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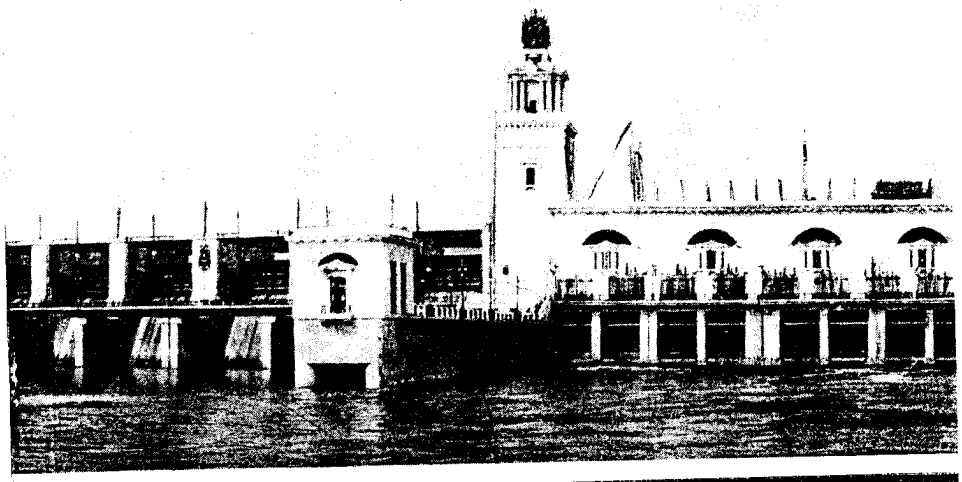
NIKOLAI RAZIN



Tsimlyanskaya

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Nikolai Razin

# THE TSIMLYANSKAYA PROJECT

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PUBLISHER'S NOTE

*The present translation has been made from the Russian booklet "The Tsimlyanskaya Project" by Engineer N. V. Razin. It gives a description of the experience gained in the building of the Tsimlyanskaya Project.*

## INTRODUCTION

Lenin's GOELRO plan (the plan of the State Commission for the Electrification of Russia) laid the foundation for a broad network of electric stations extending throughout the Soviet Union. Hydroelectric stations on the Volkhov, Svir, and Dnieper rivers, and steam plants at Balakhna, Shatura, Kashira, and Shterovka, were built in accordance with this plan.

The construction of hydrotechnical installations got well under way during the first five-year plans. The Lenin Dnieper Hydroelectric Station, the largest in Europe, was completed in a very short period of time, as were also big hydroelectric power stations on the Volga, the Chirchik, and other rivers, in addition to such huge canals as the Baltic-White Sea Canal and the Moscow Canal.

In accordance with the Fifth Five-Year Plan of the development of the national economy of the U.S.S.R. (1951-1955) the Volga-Don Shipping Canal and the Tsimlyanskaya Hydroelectric Power Station on the Don River were built, as were also the Ust-Kamenogorsk station on the Irtysh, the Mingechaur station on the Kura River, the Kuibyshev and Gorky hydroelectric power stations on the Volga, the Kakhovka station on the Dnieper, and the Molotov station on the Kama. Work is progressing apace on the Stalingrad power station, the hydroelectric station at Cheboksary on the Volga, on the Votkinsk station on the Kama, the Bukhtarma station on the Irtysh, and also on the Bratsk Hydroelectric Power Station (the largest in the world) on the Angara River, which will have a capacity of 3,200,000 kW. The total increase in the Soviet Union's



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hydro power capacity will be trebled under the Sixth Five-Year Plan (1956-1960).

The first of the huge building projects of the Fifth Five-Year Plan was the Lenin Volga-Don Shipping Canal together with the Tsimlyanskaya Hydroelectric Power Station. The joining of the two great Russian rivers—the Volga and the Don—by a navigation canal has long been the dream of the Russian people. In keeping with the demands of the country's economic development, progressive Russian people in different historical periods posed the question of joining these two rivers.

Several dozen projects for joining the Volga with the Don were advanced during the period from the 18th century to the Great October Socialist Revolution, but none of them could be realized. Pre-revolutionary Russia, being backward economically and technically, was incapable of solving such a problem. The actual construction of the Volga-Don Canal became possible only in the conditions of victorious Socialism.

The construction of the Volga-Don Canal was begun before the Great Patriotic War and was stopped during the war. In 1948, on a government decision, construction was begun anew, and at the same time new problems were posed that dealt with irrigation and water supply of the arid districts of the Rostov and Stalingrad regions. The Volga-Don project became one of the most important national-economic developments.

The builders, utilizing the best of Soviet technical achievements, the extremely rich experience in the construction of hydroelectric stations throughout the country, and the achievements of science as a whole, carried out successfully the government assignment, completing the Volga-Don Shipping Canal, the Tsimlyanskaya Hydroelectric Power Station, and an irrigation system covering 100,000 hectares of arid land in Rostov Region.

At Tsimlyanskaya the organization of construction work was based on detailed and well thought out plans and work

Fig. 1. Lenin Volga-Don Canal. General view of Lock No. 15

schedules, which stated the exact dates for the completion of different jobs, and which also provided for work methods and mechanization, including the distribution among the different construction sections of building machinery, mechanisms, and other equipment.

Work schedules determined the assignments of each construction section and created favourable conditions for widespread socialist emulation.

The workers of the project began with enthusiasm to study the new, up-to-date equipment produced at Soviet plants, and soon mastered it. Expert machine operators were trained at the construction site within a brief period of time. Many of them received a theoretical knowledge at the construction site training centre.

The government decision of December 1950 to cut completion schedules of the Volga-Don development brought forth an unprecedented wave of enthusiasm. The ground was prepared for work at all sections of the construction site; and this, together with the necessary number of high-



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power machines working at rated output, helped to organize a huge labour offensive. The workers set themselves higher targets and succeeded in fulfilling them.

On May 31, 1952, the waters of the Volga and the Don met, and on June 1, according to schedule, ships entered the locks of the Volga-Don Canal (Fig. 1). Five days later, the Tsimlyanskaya Power Station began generating electricity. At the same time, the waters of the Don passed from the Tsimlyanskaya reservoir through the main canal and distribution canal out into the irrigation fields of Rostov Region. On July 27, the Volga-Don Canal, which was named after the great Lenin, was commissioned.

The construction of the Volga-Don project was completed within a short period of time. A high-capacity hydroelectric power station and dozens of huge hydrotechnical installations were erected in difficult geological conditions. Within a three-year period, approximately 152 million cu m of earth was moved, about 3 million cu m of plain and reinforced concrete placed, and some 44 thousand tons of steel structures mounted and mechanisms installed, in addition to a great volume of other heavy work carried out.

Construction work proceeded at a rapid rate during the building of the Volga-Don project thanks to the nation-wide aid given, the enthusiasm of the builders, the complete mechanization of heavy work, and the use of up-to-date methods in handling new machinery.

During 1951 alone, over 90 million cu m of earth was moved with the highest rate approximately 14 million cu m per month and 544,000 cu m per 24 hours. In 1951, 1,980,000 cu m of plain and reinforced concrete were laid at a rate of 252,000 cu m per month and over 12,000 cu m every 24 hours.

With respect to complete utilization of the water resources of the Don, the Tsimlyanskaya hydro development occupies a central place in the technical solution of the Volga-Don project. The dam raises the water level of the river 26 metres, impounding a reservoir known as the Tsimlyanskaya Sea (Fig. 2), which stores the spring waters and ensures a regular supply of water for raising the lower reaches of the Don, as well as for irrigation and watering of the land in Rostov Region. The Tsimlyanskaya project includes a large hydroelectric station designed to meet the needs of local agriculture and industry. The hydraulic structures of this development, built on fine-grained sands, are unique.



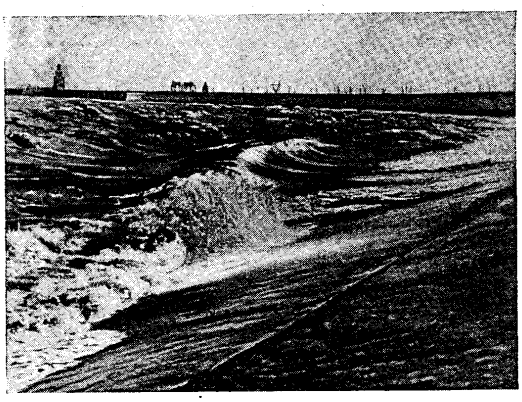

Fig. 2. The Tsimlyanskaya Sea

The rate at which the heavier work was carried out considerably exceeded records established in the pouring of concrete during the construction of the Dnieper Dam and in the hydraulic filling of Fort Peck Dam in the U.S.A.

The closing of the Don River channel in September 1951 was celebrated as an outstanding victory inspiring confidence in the builders that the construction would proceed successfully. Those at the head of the construction work (V. A. Barabanov, A. G. Cherkasov, and many others) skilfully directed this impetuous offensive towards the solu-



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tion of the main tasks leading to the final aim—the pre-schedule completion of the hydro development. In the engineering preparations of the work, of decisive importance was the well-organized, joint work of the members of the technical departments headed by G. A. Peryshkin, and the designers headed by V. P. Likhachev, K. I. Smirnov, S. V. Luzan, S. V. Titov, and others. This ensured a rapid, on-the-spot solution of all technical problems arising during the construction work, as well as a regular supply of working drawings and other project documentation.

It is necessary and timely to study and summarize the experience gained in the construction of the Volga-Don installations. The construction experience of the Tsimlyanskaya project should be of special interest, since the building conditions here are very similar to those at the hydropower station sites on the Volga and Dnieper rivers.

CHAPTER ONE

## THE TSIMLYANSKAYA PROJECT AND ITS STRUCTURES

*Purpose of the Project.* The Volga-Don waterway covers a distance of 540 km from Stalingrad to Rostov, and includes the 101-kilometre Volga-Don Shipping Canal. From the town of Krasnoarmeisk on the Volga, the canal route follows the valley of the Sarpa River, then crosses the divide and continues along the valley of the Karpovka River till its confluence with the Don near the town of Kalach. Earth dams were thrown across the valleys of these rivers, forming lakes and reservoirs. The water level in the section of the canal at the divide is 88 m above that of the Volga and 44 m above the level of the Don. Vessels from the Volga pass up through nine navigable locks before they reach the divide; then they descend to the Don River through four locks, each of which has a head of 10 to 13 m. Three pumping stations with capacities of 45 cu m per second each were built to supply the locks of the shipping canal with water from the Don and also to deliver water from the canal for irrigation purposes. The equipment of the locks, pumping stations and dams is electrically operated and provided with automatic and centralized control. A 100-km highway runs the length of the canal, which is crossed by railway and highway bridges.

The Don River in its natural conditions was of little value for navigation. The Tsimlyanskaya hydro project was built for the purpose of improving navigation conditions in addition to providing maximum utilization of the water



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resources of the Don. A spot on the Don River near the village of Tsimlyanskaya was selected as the site of the project.

The structures of the Tsimlyanskaya development include an earth dam about 13 km long, a reinforced concrete spillway dam about 500 m in length, a hydroelectric power station, a fishway, a shipping canal with two locks, and the headwork of the irrigation canal.

A port and timber trans-shipment base, sheltered from the reservoir by breakwater dikes, were built in the immediate vicinity of the project. Settlements for operation and maintenance personnel went up on the west and east banks.

The Tsimlyanskaya dam raises the water level in the river 26 m, forming a reservoir with a surface area upwards of 2,600 sq. km. This reservoir offers the following economic advantages:

1. The Tsimlyanskaya hydroelectric station generates cheap electricity.

2. The Tsimlyanskaya reservoir forms a deep waterway for vessels proceeding from the Volga-Don Canal to the hydro development. The sailing distance on this section is reduced from 245 to 186 km. Sufficient depths for the passage of vessels are maintained throughout the period of navigation, whereas prior to the building of the hydro project, navigation was possible only during the high water period in the spring.

3. The Tsimlyanskaya reservoir, or sea, as it is called, provides for the irrigation and watering of the arid land in Rostov and Stalingrad regions.

4. Fisheries can be organized in the Tsimlyanskaya reservoir. At present this work is in progress.

Extremely important economic problems have been solved by the commissioning of the Volga-Don Shipping Canal, the Tsimlyanskaya hydro development, and the irrigation canals.

The Volga-Don system links five seas by interior waterways. A direct route passing through the entire country



from the Arctic Circle to the subtropics has been opened to navigation. The capital of our country—Moscow—has become a port of five seas. The Black Sea is now connected with as many as 30 thousand kilometres of navigable rivers that form the Volga and North-Western basins. The Volga now carries shipments of Donbas coal, metal, grain, fish, and fruit, and the Don handles shipments of timber, chemical products, motor vehicles, tractors, and paper.

The Tsimlyanskaya power station will permit electrification of the agriculture and the industrial establishments of the surrounding territory. The use of electric power will make it possible to improve irrigation farming and many other branches of agriculture.

The districts of Rostov Region and the southern districts of Stalingrad Region have often suffered from droughts and crop failures, despite the abundance of warmth, sunlight and fertile soil. Before the Revolution, approximately 12,000 hectares of land (chiefly gardens, orchards, and vineyards) were irrigated on the territory of present-day

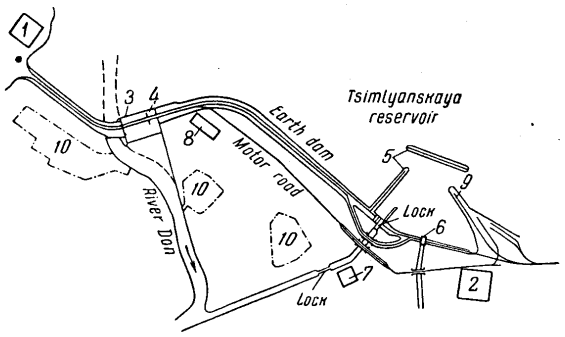


Fig. 3. General layout of Tsimlyanskaya Project

*1* and *2*—Settlements on the east and west banks for maintenance personnel; *3*—Reinforced concrete spillway dam; *4*—Powerhouse; *5*—Breakwater dikes protecting the harbour; *6*—Intake works of the irrigation canal; *7* and *8*—Concrete plants; *9*—Mooring pier; *10*—Sand borrow pits for hydraulic filling.



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Rostov and Stalingrad regions. During the years of Soviet power the area under irrigation reached 50,000 hectares, and in 1952, with the completion of the Volga-Don project, an irrigation system covering 100,000 hectares of land in Rostov Region went into operation.

Wheat, rice, cotton, maize, alfalfa, fodder crops, fruit trees, grapes, vegetables, and potatoes are now raised on the irrigated land. The number of Don horses, as well as large-horned cattle, sheep and swine, will be increased on the territory supplied with water in the region of the Don. Livestock productivity will rise two- and three-fold, and the productivity of the irrigated lands, five-fold and more.

*Layout of the Project.* The layout of structures shown in Fig. 3 was selected with account taken of the hydrological peculiarities of the river, the local geological and topographical conditions, organization and methods of construction. The question of economy was also taken into consideration.

A feature of the Don River at the construction site is the intensive rise in the water level up to 8 m during the spring flood period when the flood plain of the Don is covered with three and four metres of water. After the spring flood, the water falls to its average level and remains so except for slight rises during the summer-autumn high water. The river freezes over at the beginning of December and opens up at the end of March.

The river valley where the structures are located is composed of sand, loam, and clay. The flood plain deposits are characterized by filtration anisctropy. Complex geological-

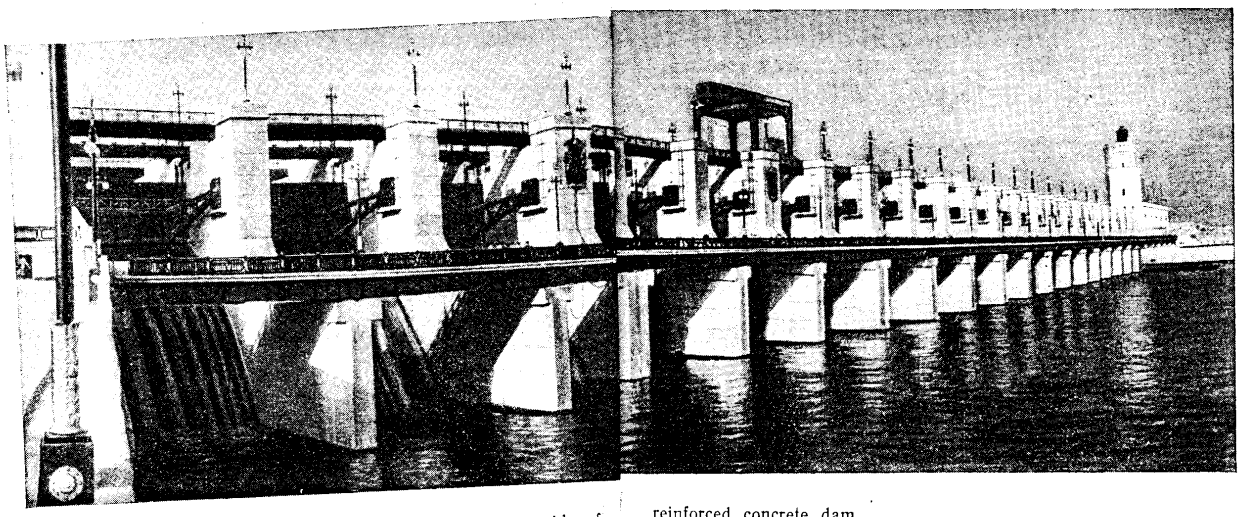

Fig. 4. Downstream side of reinforced concrete dam





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engineering conditions required new-type structures. The best Soviet engineers and scientists participated in the designing work which was headed by Academician S. Y. Zhuk.

The construction of huge hydrotechnical structures in such complex geological conditions became possible thanks to the rich experience of Soviet builders and the achievements of Soviet science. By way of illustration it may be mentioned that only recently, during the construction of the Parker hydro development on the Colorado River in the U.S.A., American engineers excavated to a depth of more than 80 m for an effective head of approximately 22 m in order to avoid erecting the structures on alluvial soils. At the same time, large dams and hydroelectric stations with foundations on compressible soil were built in the U.S.S.R. on the Svir and Volga rivers. The erection, on fine-grained sands, of the still larger structures of the Tsimlyanskaya project is a new achievement in hydraulic engineering.

The spillway dam together with the powerhouse and fishway is a single reinforced concrete structure approximately 600 m in length, flanked on both sides by an earth dam. This structure is situated on the east-bank flood plain in a bend of the Don River.

*The Spillway Dam* (Fig. 4) is designed to pass spring high water at a rate of 35 cu m a second per linear metre on the down apron. The specific kinetic energy of the water flowing over the crest of the spillway is of the order of 8,000 kW. In order to protect the structure from scour and to dissipate the energy of the flow, and reduce its velocity to that of the river, baffle piers were installed at the toe of the spillway to break up the flow; in addition, a sill was put up behind the piers (Fig. 16), where the flow rate is reduced to five and six metres per second.

The stilled flow is then directed along the down apron slabs that fall gradually to the bucket which is overlaid with stones. These stones cover depressions that may appear due to local erosion of the river bed. Flow velocities on the down apron are reduced to 1.8 and 1.0 m per second, which corresponds to high water velocities on the Don River in its natural state.

The paths of percolation from the reservoir under the structures are lengthened by means of a watertight upstream apron with two rows of steel sheet piling driven into the marly clay of the upstream bed. This arrangement, together with the drainage systems, reduces seepage, cuts uplift due to water seeping under the dam, and prevents small particles of soil from being washed out from under the structures by the percolating water. The path of percolation at the joint of the spillway dam and the electric station was also lengthened by building cut-off walls made of steel sheet piles.

The dam is made of reinforced concrete capable of withstanding additional loads due to uneven settling. One of its features is a large upstream foundation slab which, on the one hand, increases stability against shear due to surcharging of the extended part of the slab by water, and, on the other hand, makes for an even distribution of pressure on the foundation soil.

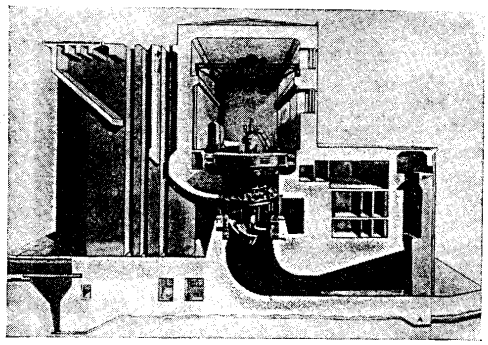

Fig. 5. Schematic cross section of powerhouse





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*The Hydroelectric Station* with a capacity of 160,000 kW (a cross section of it is shown in Fig. 5) together with the fishway is a head structure. Due to the conditions of ground pressure distribution and structural stresses, the structure is divided into two sections by an expansion-settlement joint: the shore section with the assembly grounds and the river section with the fishway.

As in the case of the spillway dam, the powerhouse has a foundation of fine-grained sands. For this reason, the design of the upstream apron, the down apron, and drainage system is the same as that of the spillway dam. As flow velocities at the outlet of the turbine draft tubes do not exceed 3.0 m per sec., the toe apron of the power station dispenses with energy dissipators.

The turbines and generators of the Tsimlyanskaya hydroelectric station (Fig. 6) are of the latest design. A structural feature of the hydro units is the position of their pivots on the turbine cover plate, which makes it possible to reduce the height of the units, their weight, and also the dimensions of the machine hall. The new design of the hydro units was worked out on the basis of the extensive experience of Soviet industry, at the Leningrad Metallurgical Works and the Leningrad Elektrosila Plant, the Novo-Kramatorsk Plant, and others.

A 45-ton grab crane is used for raising the trash racks and dam beams, and for cleaning the intake chamber.

The rapid-drop gates have separate mechanisms; and there are two overhead travelling cranes in the machine hall for installation and repair of hydro units.

The power station is equipped with the latest devices and instruments for automatic control.

The central control board, the generator voltage switchgear, as well as the compressor and oil systems, and other auxiliary equipment, are housed in closed rooms in the powerhouse.

*The Fishway* (fishhoist). The purpose of the fishway is to allow sturgeon and fishes of the type caught in close-



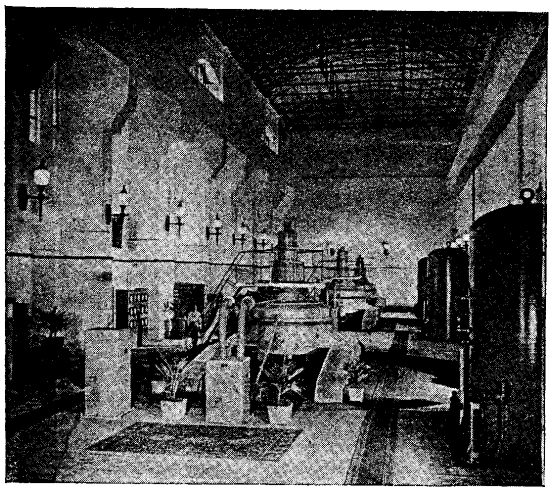

Fig. 6. Turbine room, Tsimlyanskaya Hydroelectric Station

meshed seines to pass upstream into the reservoir. It consists of a reinforced concrete head race on the downstream side (downstream pier), a fishhoisting lock, 6.2 by 5.0 m, which conveys the fish from tailwater to headwater, and an exit upstream pier in the reservoir. The downstream and upstream piers serve simultaneously as dividing walls in the headwater and tailwater of the powerhouse and the spillway dam. A cross section of the fishway is shown in Fig. 7.

Passage of the fish through the fishway takes place as follows: the fish passing upstream to spawn are "attracted" (by the flow of water) to the power station and the downstream pier of the fishway. Large fish cannot approach the draft tubes of the powerhouse because of a metal protec-



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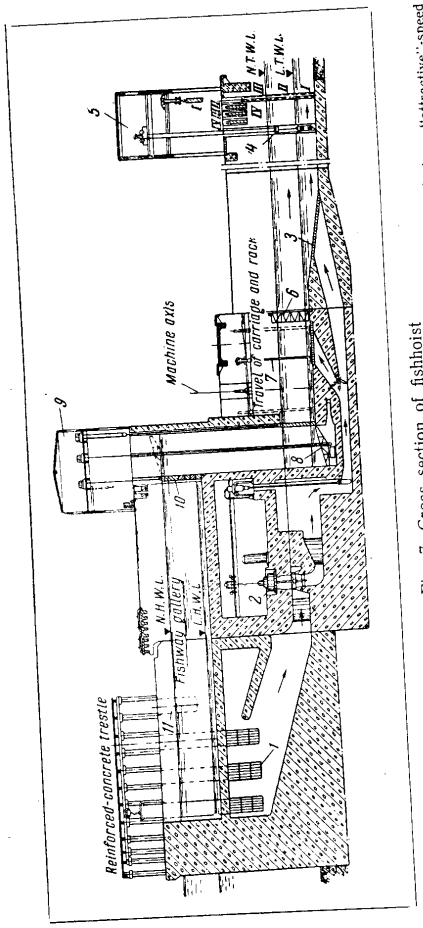


Fig. 7. Cross section of fishhoist

*1*—Inlets in upstream pier for conveying water to turbine; *2*—Low-power unit with turbine producing "attractive"-speed currents; *3*—Flow distributing rack; *4*—Downstream-race gate; *5*—House with hydraulic gear of hoist; *6*—Steel gates at entrance to pond; *7*—Moving rack to urge fish on; *8*—Steel lock-chamber hoist; *9*—House with hydraulic gear of hoist; *10*—Inlet dam beams to upstream pier race; *11*—Fish outlets in upstream pier; *I, II, III, IV*—Downstream-race dam beams. Arrows indicate direction of flow.



tion net placed from the end of the downstream pier to the shore at an angle of 45 degrees. The fish move along the net and approach the entrance, opening into the downstream-pier race, in which "attractive" current speeds are formed by a special small-size turbine that serves the fishway.

The fish pass along to the end of the race into a "pond," whence, with the aid of a special moving rack, they are driven into the shaft of the vertical lock which is provided with a metal lattice-elevator that raises the fish to headwater. As the elevator rises, the lock chamber fills with water to headwater level. The fish then enter the reservoir through the upstream pier which has special outlets.

All these operations proceed consecutively in the form of a cycle. Control of the machinery is completely automatic, thus fully ensuring the correct sequence of operations in the passage of the fish up the fishway.

*The Earth Dam*, in length and volume, is the largest of its kind in the Soviet Union and one of the largest in the world. The total length of all the head structures of the project is 13.5 km, of which the earth dam accounts for 12.75 km. The whole west-bank dam (Fig. 8) and a considerable part of the dam on the east bank were built up of sand placed hydraulically; the remainder of the east-bank dam was built of local sandy loam with each layer of earth fill rolled.

The total volume of the dam body is approximately 32 million cu m, of which about 29 million cu m was placed hydraulically and 3 million cu m of sandy loam dumped.

A cross section of the hydraulic-fill earth dam shows it to have a flattened profile which makes for stability.

In order to prevent freezing and the formation of ice crusts during the winter, a closed-type drainage system consisting of 800-mm dia pipes (Fig. 43) covered with an inverted filter was built along the downstream slope of the dam. The water that collects in the drainage pipes is discharged through cross outlets into the Don and the Solyonaya rivers. The total amount of seepage accumulated by



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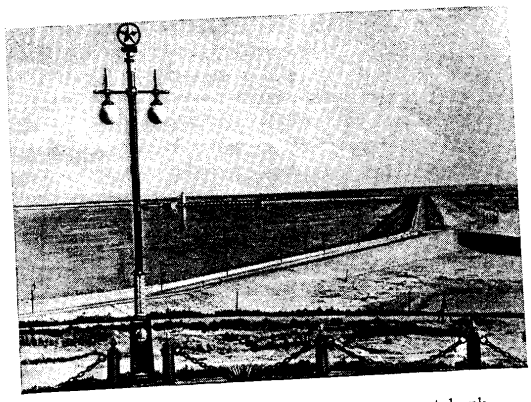

Fig. 8. General view of earth dam from west bank

the drainage system of the dam as a whole at full head is expected to be of the order of two cubic metres per second according to calculation estimates. The sandy-loam dam has a simpler, inclined drainage system.

The width of the base of the dam varies according to height. The crest of the dam carries a railway line and a concrete-covered service highway with walkways for pedestrians.

The reservoir slopes of the dam are covered with reinforced concrete slabs that protect the dam from the eroding action of the waves; on the crest, the concrete reinforcement ends in a wave-break parapet. The downstream sand slope of the dam is reinforced with a layer of crushed stone 10 cm thick as protection against wind erosion.

*Canal Structures.* The shipping canal with two locks connecting the reservoir with the tailwater of the Don River is situated on the lower and upper flood-plain terraces of the east bank; the canal enters the river at the bend below the site of the dam. This location of the canal structures was



dictated by the two-step lock system with an intermediate channel between the locks, which was believed the most advantageous of all the systems considered in the project.

The 5.5-km route of the canal from the upstream end of Lock No. 14 (Fig. 9) to its emergence into the Don was calculated to reduce excavation work on the canal to a minimum. The natural step formed between the upper and lower flood-plain terraces was utilized to advantage for the siting of Lock No. 15, which opens the way to vessels passing from the Don into the Volga.

The intermediate channel between Locks No. 14 and No. 15 is 1.6 km in length. The slopes of the canal, within

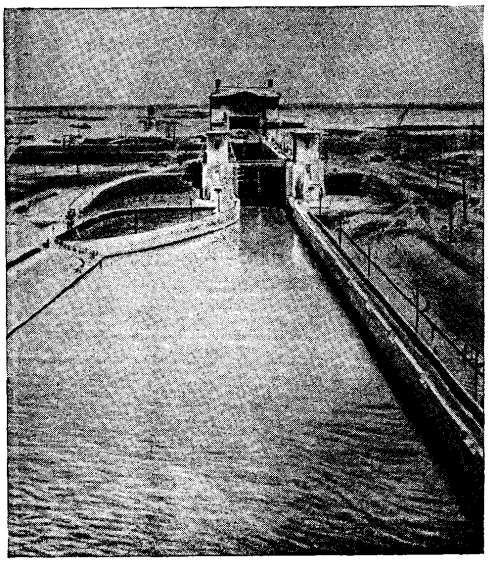

Fig. 9. General view of Lock No. 14



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the range of water-level variation, are paved with stone on a three-layer filter. The downstream canal, from Lock No. 15 to its emergence into the Don, is 3.5 km in length, and the slopes are paved in the same manner. A 25-m lighthouse was built on the shore at the entrance to the canal from the Don River.

The lock chambers are of reinforced concrete with a solid bottom cut in two by a joint. The ends of the locks have uncut bottoms to prevent tilting of the piers in the case of settling since this could interfere with the packing and the work of the gates.

The chamber of Lock No. 14 is filled with water through conduit galleries located in the upstream end of the lock, and emptied through galleries of the same type in the downstream end. Special devices have been installed to dissipate the energy of the water during filling and emptying.

The chamber of Lock No. 15 is filled with water from under flat-drop navigation gates, since the absence of sharp variations in the water level of the intermediate channel permits this type of gate to be used; this simplifies the design of the upstream end of the lock and reduces the volume of reinforced concrete. The lock chamber is emptied in the same way as in Lock No. 14, i.e., through conduit galleries in the downstream end.

The navigation gates of the locks are of the double-leaf multi-spanner metal type, with the exception of the navigation gates of the upstream end of Lock No. 15.

In addition to the navigation gates, double-leaf repair gates, lighter in design and less in height, were installed, with the exception of the upstream end of Lock No. 14, where an emergency flat gate was installed. When not in use, this gate is raised into the arch connecting the control towers of the upstream end of the lock.

A special reinforced concrete pipe is used to add water to the intermediate channel. This pipe discharges water directly into the intermediate channel by-passing the lock chamber. There is a pipe of the same type on Lock No. 15 for discharging excess water from the intermediate channel into the downstream channel.



Control towers containing the lock gear and the lock control switchboards are located on the piers of the upstream and downstream ends. Control of the lock gear is automatic, thus ensuring rapid lockage. It takes 9 minutes to fill the chamber, emptying takes 8 minutes, and the whole cycle of locking with entrance and exit of vessels takes 36 minutes for one-way locking and 52 minutes in the case of simultaneous locking for vessels going in both directions.

Mooring lines for the mooring of ships awaiting passage through the locks and a row of piles that guide the ships as they enter the lock have been placed at the upstream and downstream lock entrances. The mooring lines are reinforced concrete walls on a pile foundation.

On the walls are mooring bitts and rings (hooks); the lock chambers have, in addition to stationary rings, floating rings of a special design to facilitate mooring of vessels as

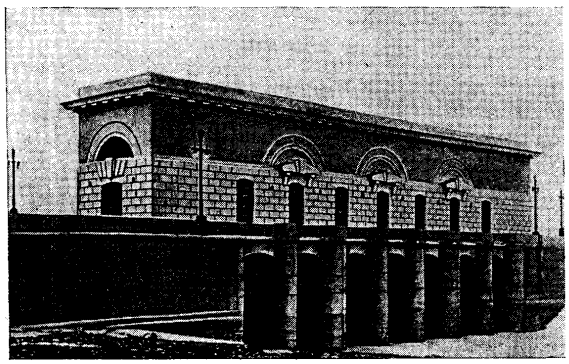

Fig. 10. Headworks of irrigation canal



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they rise and fall with the changing water level in the chamber during lockage.

Since the future development of navigation may require a second canal line, during the construction of the earth dam the lower part of the upstream end of a future second lock was built.

The outer harbour at the approaches to Lock No. 14 provides for the calm entrance of vessels into the lock or their anchorage in the case of high waves in the reservoir. One of the dikes of the outer harbour is at right angles to the earth dam on the east side of Lock No. 14, and a second dike of the same length is located in front of the earth dam, thus protecting the entrance to Lock No. 14 and the wharf of the Tsimlyanskaya port from the reservoir.

The entrance to the outer harbour from the reservoir is situated between the ends of the dikes. A lighthouse was built on the end of one of the dikes, and a signal sign on the end of the other. The slopes of the dikes facing the reservoir are protected with reinforced concrete slabs, while those facing the outer harbour are paved with stone.

The Tsimlyanskaya port is located in the southern part of the reservoir and handles passengers and trans-shipment of freight. The port wharves are in the form of a wall of steel sheet piling and the breakwater has the form of wooden frames. Service buildings, passenger rooms and warehouses are situated on the territory of the port which was formed by fill.

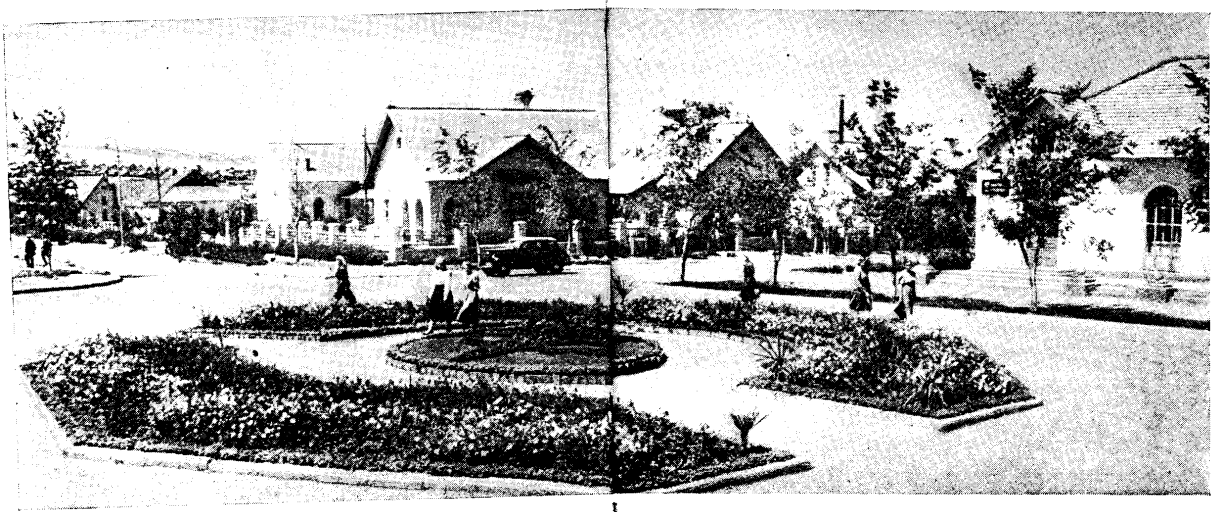

Fig. 11. A street in one of the settlements for maintenance personnel





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Loading and unloading operations in the port are mechanized; the basic mechanical equipment consists of electric portal cranes, loaders, belt conveyors, crawler cranes, and a freight elevator.

The timber yard is located next to the port and is designed to handle the trans-shipment of timber (arriving in the form of rafts) to railway cars for transportation to the Donets Coal Basin and the woodless regions of the southeast. A section of the water is marked off for storing and sorting the timber as it arrives. Mooring booms run the length of this section.

The work of getting the timber out of the water and loading it into railway cars is mechanized. Self-propelled gantry cranes, log hauls, conveyors and other equipment are used.

*The Purpose of the Headwork* of the main irrigation canal (Fig. 10) is to take in and regulate the water supply entering the irrigation system from the reservoir, and also to feed the Manych waterway.

The headwork is located in the body of the earth dam south of Lock No. 14 and is in the form of a multi-cellular non-pressure reinforced concrete pipe. Flat steel gates are placed at the pipe openings to regulate the water flow. On the reservoir side, the intake has an entrance head with an upstream apron, and on the downstream side an exit head with a down apron provided with reinforced concrete baffles or energy dissipators, to reduce the water flow velocity into the canal.

The gear operating the gates of the water pipe is located above the pipe in a special building that also houses the control switchboard.

*A town* for the maintenance personnel of the shipping canal installations, the port and timber yard, is situated on the east bank; and on the west bank is a town for the personnel of the power station.

The towns have durable buildings provided with all the conveniences of modern living and also with all the necessary service and welfare establishments and public buildings.

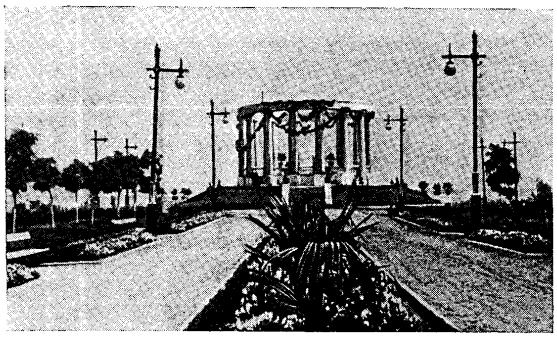

Fig. 12. A park in one of the settlements for maintenance personnel

The dwellings are one-storey (cottage-type) and two-storey buildings containing several flats each (Fig. 11). The bigger houses and public buildings have central heating, while the cottages are heated by stoves. All buildings have running water and sewer systems, and the streets and pavements are asphalted. In each town there are parks, in addition to trees and shrubbery planted along the streets and in the yards (Fig. 12).



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CHAPTER TWO

## MANAGEMENT AND STAGES OF CONSTRUCTION

*Management.* Characteristic of the Tsimlyanskaya development is the enormous size of the structures, their technical complexity, the huge volume of building and erection work and the brief time limits during which up-to-date machinery and construction techniques were mastered. The total volume of the main types of work that confronted the builders was as follows:

| | |
|---|---|
| Earth work | 92,000,000 cu m |
| Plain and reinforced concrete | 1,960,000 cu m |
| Rock-fill work and filter-drainage systems | 1,779,000 cu m |
| Rock slope-protection (excluding fascine protection) | 660,000 sq. m |
| Steel sheet piling | about 14,000 tons |
| Steel structures and machinery | about 23,000 tons |

In order to accomplish such an immense volume of work within the short period of time allotted, it was necessary first of all to establish a large-scale production base with the requisite industrial and auxiliary enterprises and buildings; to build a network of transportation lines, workers' towns, storehouses, and also to establish power supply and a system of communications. A second indispensable condition was the mechanization of all heavy work by using powerful up-to-date machinery.

The operation of the vast number of different-type machines and industrial undertakings, and the handling of the huge flow of building materials, required well-organized work in every branch of management on the construction job.



Management of the work was organized according to the following structural scheme: Construction Board, Construction District, Construction Section, and Construction Superintendents.

Construction districts had their own finance-accounting system and carried out all the construction work; together with the contractors they handled all the erection work at the different sites.

District No. 1 covered the canal structures; District No. 2, the east-bank earth dam; District No. 3, the spillway dam and the powerhouse; District No. 4, the west-bank earth dam and the west-bank maintenance personnel town, and District No. 5, the dry-fill work on the earth dam, the irrigation headwork, the port, timber yard, outer harbour and east-bank town.

A number of specialized divisions were organized in addition to the basic construction districts. Among them were: the manufacture and assembly and erection of reinforcement, the production of concrete mix, the building of forms, the manufacture of reinforced concrete slab panels, power supply, drainage and boring work, railway and water transportation, etc. Hydraulic-fill work was carried out by a special Hydraulic-Fill Management on a contract basis.

Special-type jobs were carried out by the contractors as follows: sheet pile driving was handled by Fundamentstroi of the Ministry of Construction; the erection of steel structures, gates, and the installation of machinery by Gidromontazh; hydro power equipment by Spetsgidroenergomontazh, and electrical equipment by Donbasenergomontazh of the Ministry of Power Stations.

The Central Repair Works was under the Chief Mechanic of the construction site, and the auto-repair works was in the motor vehicle department of the Construction Board.

Machinery and motor vehicles were placed entirely at the disposal of the different construction districts, within which (according to the volume of work and the number



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of machines) were organized sections of mechanized work, tractor sections, transportation offices, and motor depots. Also a permanent training centre was established at the construction site.

The Construction Board superintended the work through the following departments: technical, production, erection, motor vehicle and planning departments, the flood-area department, the departments of the Chief Mechanic, the Chief Power Engineer, and others. Control of the quality of the work was exercised through the technical inspection department, the laboratory of building materials and the geotechnical laboratory; the latter two were under the Chief Engineer of the project.

All surveying and designing, including the preparation of the working drawings, was carried out by Gidroproekt with a part of the work done by specialized designing organizations. A permanent division of Gidroproekt was located at the construction site for coordinating and settling of all project problems as they arose during construction; it also exercised a so-called "designer" supervision at the construction site.

The local observatory supplied the project with information concerning hydrology and climate.

*The Order of Erection of the Structures.* Organization of construction work was regulated to a large extent by the conditions under which the most complex structures (the dam and powerhouse with 1,200,000 cu m of reinforced concrete work) would be erected. The dam and powerhouse, located on the east flood plain in a bend of the Don River, were protected during construction by cofferdams which narrowed the river channel. After the Don channel was closed, the discharge was passed through the bottom sluiceways of the dam.

The earth dam, with a volume of approximately 32 million cu m, was mainly hydraulic-filled from nearby floodplain deposits of sand. Excavation work on the canal locks and headworks of the irrigation canal was done in the dry.



The sequence of construction was determined by two basic conditions: the construction schedule, which specified the completion time of each structure, and the scheme for passing the discharge during construction.

Correspondingly, all construction work at the project may be divided, chronologically, into three consecutive stages: stage one—the setting up of a production base and preparation for large-scale earth and concrete work at all sites; stage two—the erection of the underwater parts of the reinforced concrete structures of the dam and powerhouse, the closing of the Don River channel, and the hydraulic filling of the earth dam; stage three—the completion of the structures, and the installation and final testing of the basic technological equipment, and the commissioning of the project.

*First Stage of Construction.* This stage lasted from the middle of 1949 to the end of 1950. During this year and a half, about 20 million cu m of earth was moved, approximately 100,000 cu m of plain and reinforced concrete placed, and 1,700 tons of metal sheet piling driven.

In line with the workers' desire to cut completion time-schedules, the output capacity of the production establishments was expanded.

First of all, the network of railways and motor roads on the territory of the construction site was considerably extended. It should be mentioned that the construction of the required length of motor roads was completed by the middle of 1951. The production of concrete was increased. Beginning with the second quarter of 1951 the 24-hour output of the five concrete plants reached approximately 7,000 cu m of concrete.

The Central Reinforcement Works was also expanded and reconstructed with a 24-hour output of more than 300 tons of reinforcement. In addition, a second reinforcement section was established to supply the needs of the canal structures. All reinforcement work was concentrated in a separate specialized district entrusted not only with the



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manufacture of reinforcement but also with the erection of reinforcement structures directly in the blocks.

Work was begun simultaneously on the construction of a special plant for the production of reinforced concrete slab panels, which were widely used at the project. This plant began operation in the second quarter of 1951.

The woodworking factory at the site began operation in 1949, and after installation of additional equipment it was ready for the production of form frames.

Among the urgent measures, upon which depended the construction of the main installations, it is necessary to include that of supplying the construction site with electric power. In addition to temporary diesel-engine stations, the site had, by September 1950, two power trains, and a power transmission line from the Rostov power system.

During this same period, suction dredgers (types 300-40 and 500-60) began regular operation. They handled the excavation work for the spillway dam and also pumped their spoil into the cofferdams and, at several points, into the body of the earth dam. By the end of 1950, the dredgers had delivered about 100,000 cu m of sand to the concrete plant yard. The total volume of work accomplished by all the suction dredgers by the end of 1950 amounted to approximately 7,000,000 cu m.

The ESh-1 dragline excavators (bucket capacity 3.4 cu m) produced at Soviet plants passed all tests successfully and began operation. 3-cu m "Uralets" electric shovels and other excavators with dippers of various capacities were placed in the cut. 6-cu m scrapers and bulldozers were widely used.

Up until the end of 1950, i.e., before delivery of concrete by rail was begun, the concrete mix was delivered to the construction site by motor vehicles only; use was made of MAZ-205 and ZIS-385 lorries, and also ZIS-150 lorries specially equipped for the transportation of buckets.

The most responsible technical task of this period consisted in protecting the excavation pit of the concrete struc-



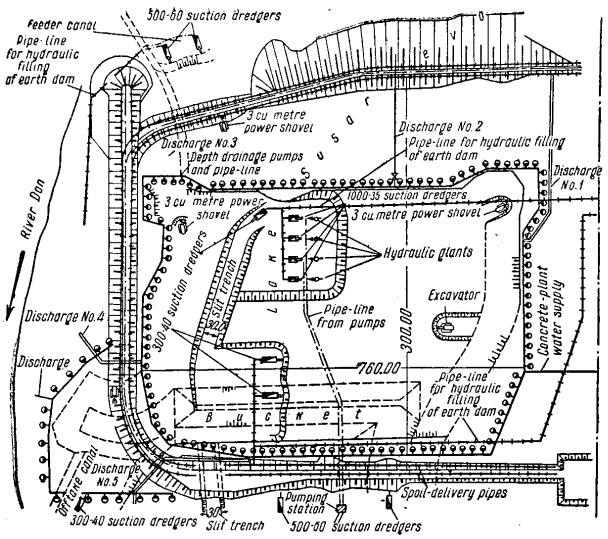


Fig. 13. Organization of operations in dam and powerhouse excavation pit

tures by a cofferdam, and in draining it. This was necessary in order to cut it down to grade with the help of dry earth dredgers (Fig. 13). The three-kilometre cofferdam protecting the excavation on three sides was built of sand sluiced into place during excavation of the pit by suction dredgers. This work was completed before the high water of 1950.

The second extremely important task of this period was the driving of metal sheet piling in two rows within the area of the reinforced concrete upstream apron and at its point of contact with the mass concrete. It was not possible to begin mass-scale pouring of concrete in the main body of the dam and powerhouse or to begin work on the upstream apron before the sheet piling had been driven. The





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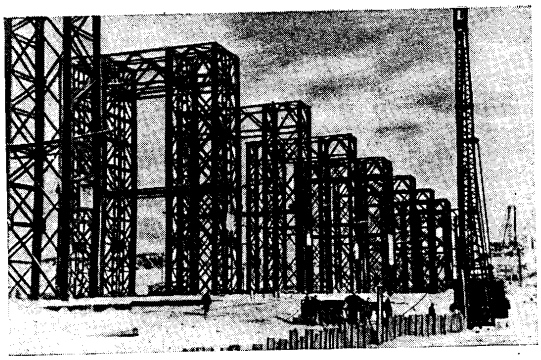

Fig. 14. Supports of steel concrete-delivery trestle

volume of this latter work on the spillway dam and powerhouse alone amounted to 9,200 tons and, therefore, the work had to be considerably accelerated.

The third task, which determined the high rate of concrete work, was the erection of a concrete-delivery trestle (Fig. 14) in the dam pit. It was 700 m in length and 25 m high; the weight of the metal supports and span structures came to approximately 8,000 tons. The 36 concrete bases of the supports (with a total volume of 7,000 cu m) were located below the toe of the dam.

The pit of nearly every support had to be drained with well-points, and in order to complete the concrete work on all supports it was actually necessary to complete the pit excavation work. Erection of the trestle was successfully completed in November 1950.

During this same period, work on the locks and ship canals and also on the foundation for the hydraulic-fill earth dam got well under way. Silt soil in a plastic state was discovered during foundation work on the west-bank



earth dam, necessitating the excavation below grade of an additional 600,000 cu m of earth. This work was handled by draglines together with a rather extensive open drainage system.

By the end of 1950, the construction site was prepared for work to proceed on all structures.

*Second Stage of Construction.* Work on the Tsimlyanskaya hydro project reached its highest point of intensity in 1951. During that year, 49 million cu m of earth work was accomplished, 1,266,000 cu m of plain and reinforced concrete placed, and 10,600 tons of sheet piling driven, not counting many other jobs.

The central task at the Tsimlyanskaya construction site in 1951 was the closing of the Don River channel. The aim was to shift the discharge of the Don to the concrete structures by the middle of September 1951, which would make it possible (in the hydraulic-fill work) to reach the design levels of the highest part of the earth dam in the river channel during the remaining warm part of the year. Filling of the storage reservoir was scheduled to begin early in 1952, that is, when the dam would be ready to withstand a head.

Due to the delay in sheet pile driving, work was especially held up on the upstream apron. It was decided to pass the discharge through the 10 bottom sluices of the extreme west-bank sections of the dam, with part of the upstream apron of the remaining sections excluded. For this purpose, a longitudinal cofferdam was built on the ready part of the upstream apron, and along the spillway part of the dam on the downstream side concrete was placed ahead of schedule, thus forming a concrete cofferdam that protected the unfinished part of the upstream apron of the dam from being flooded.

The volume of reinforced concrete work had by this time reached the figure of 760,000 cu m. During the winter months of 1951, the rate of concrete pouring was low and during the first three months the total amount of concrete



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placed was less than 80,000 cu m. It was necessary, therefore, to speed up this work within a very short period of time.

In April, 90,000 cu m of concrete was placed, in May, 120,000 cu m, and beginning with June the monthly volume of concrete placed was between 140 and 153 thousand cu m, reaching 6,000 cu m and more in a 24-hour workday. During this period, 8 to 10 thousand tons of reinforcement was being produced monthly.

During this same period, big and complex jobs were accomplished on the flexible down apron, the fascine reinforcement of the bucket, the relief wells of the down apron and in the building of a temporary feeder canal and diversion canal. The flexible down apron, covering an area of more than 20,000 sq. m and made up of pre-assembled reinforced concrete slabs, was put in place chiefly with the aid of crawler cranes and auto cranes. In building the relief wells, the method used was that of putting into place filters of prefabricated blocks that were formed of materials

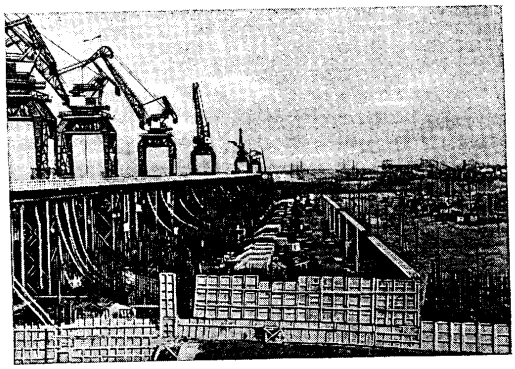

Fig. 15. General view of spillway dam before flooding of tailwater area from the Don River



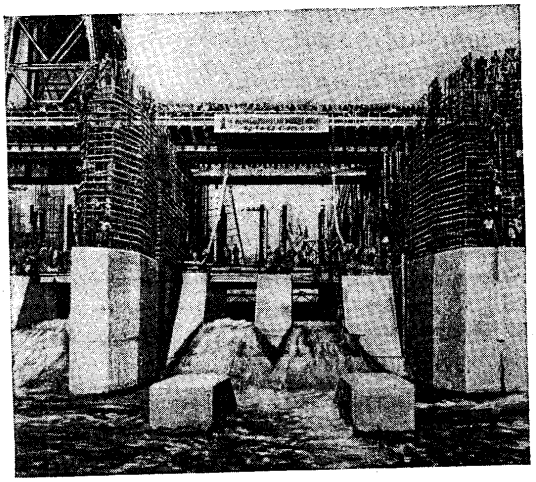

Fig. 16. Water being discharged through bottom sluiceways of dam

of the required particle size. A sulphite-alcohol wash, which rapidly dissolves in water, was used as a binding agent.

Modified BU-20-2 derricks and special mechanisms designed at the site to draw out pipes were used successfully in building the drainage system.

Thus, by the time the Don River was closed, the underwater part of the spillway dam and powerhouse, with the exception of the protected part of the upstream apron, had been completed (Fig. 15) and accepted by the inspection commission.

On September 16, the feeder canal was filled with water after which the dam gates in the bottom sluiceways of the dam (Fig. 16) were opened and the tailwater area was flooded (Fig. 17).



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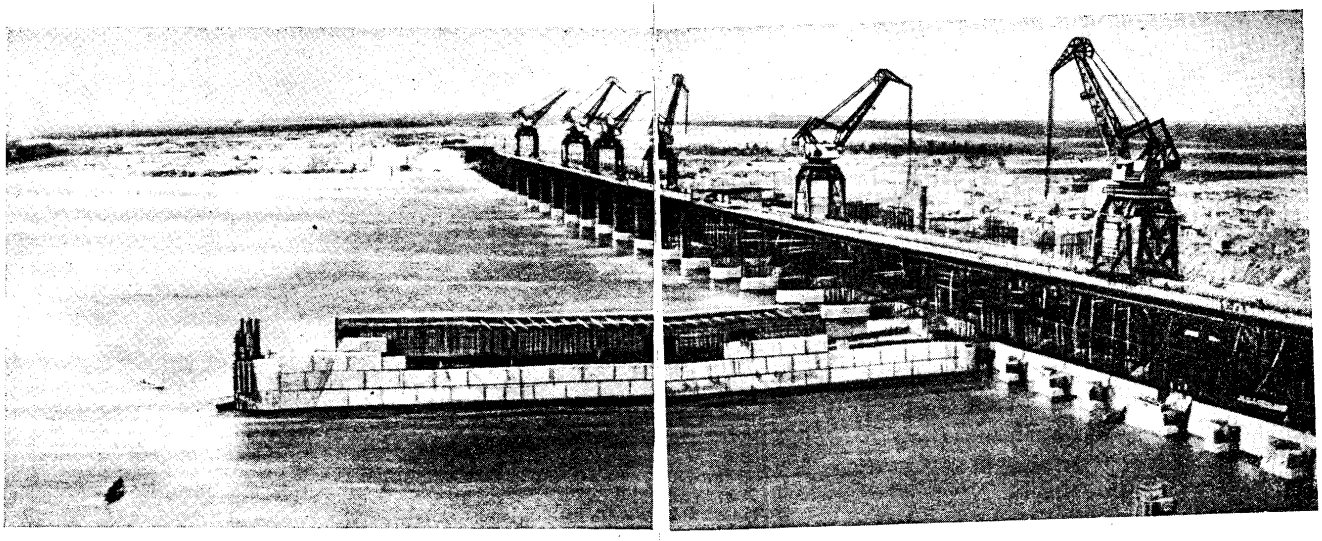

Fig. 17. General view of spillway dam with tailwater area flooded.

On September 21, at 7 p. m., after the downstream cofferdam in the diversion canal was partially dismantled, tip-up lorries began to dump rock into the Don River to close up the 80-metre gap in the old channel. In four hours, with 380 cu m of rock tipped every hour, the rock appeared above the surface of the water throughout the width of the gap; in 8 hours the Don was stopped by the rock fill. Simultaneously, intensive hydraulic filling of the river channel part of the dam was begun, and 24 hours later the Don channel was entirely closed. This was the end of one of the main stages in the building of the project.

A second, and no less responsible, job in 1951 was the building of the earth dam. Rolled-fill and hydraulic-fill work on the dam had to be completed in 1951 in order to



make completion of the slope protection and the drainage system possible by the spring of 1952; otherwise the dam would not be able to hold back the water.

Thanks to the timely preparation of the dam foundation and to the well-organized dredging (the number of hydraulic dredgers was sufficient), the hydraulic-fill dam of the Tsimlyanskaya development was actually completed in 1951 alone, when 24 million cu m of earth was placed in the body of the dam. And the river channel part of the dam (35 m in height, 600 m in length and 3 million cu m in volume) was built in 1951 in the course of two months.

The fill of the dam on the sector from the lock to the east-bank abutment (a total of 3 million cu m) was dumped of loess-type sandy loam. Scrapers filled in the lower lay-



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ers while the remaining part was handled by tip lorries loaded by 3-metre power shovels. The fill was rolled by sheepsfoot rollers. The building of the headwork of the main irrigation canal was in progress as work continued on this section of the dam.

The third task of 1951 was the building of the shipping canal structures.

The excavation of Lock No. 14 was done by power shovels with the earth deposited into a railway fill. The intermediate channel between locks Nos. 14 and 15 was excavated in the same way. The well-point method of drainage was used in the excavation of Lock No. 14, the greater part of which was situated in soils with a low water content.

The greater part of the concrete mix was placed in the lock and the approaches to it with the aid of conveyors, and only a small part was handled by three-ton portal cranes and crawler cranes. These same cranes handled the mounting of reinforcement frames, reinforced concrete slab panels and wooden form frames.

Excavation of Lock No. 15 required the use of depth drainage which was accomplished in the form of a ring of 27 depth pumps positioned along the outer perimeter of the excavation, with the water delivered to a common collector; in addition to drainage by depth pumps, considerable use was made of well points for local reduction of the water level in the pit bed.

Placing of concrete in Lock No. 15 was begun in the middle of 1951. As was the case with Lock No. 14, conveyors were used to place most of the concrete mix. The mounting of reinforcement frames, reinforced concrete slab panels, and wooden form frames was handled by crawler cranes and cable cranes with a hoisting capacity of 8 tons and a span of 230 m.

During the excavation of the lower part of the shipping canal (from Lock No. 15 to the Don River) considerable difficulties were met with due to rather unstable soil and a high water table on certain sections of the canal. Work



throughout the length of the canal was begun in the middle of 1950 with 6-cu m scrapers stripping the overburden. The main excavation work on the canal was done by ESh-1 draglines, which dumped the soil beyond the edge of the canal. A drainage trench was dug down the middle of the canal bottom by a 100-35 suction dredger.

During the high water of 1951, a part of the canal was cut off by an earth cofferdam which enabled excavators to continue on the section from Lock No. 15 to the cofferdam during the high water period. Bulldozers were used for trimming the slopes and for leveling off spoil on the edges of the canal.

*Third Stage of Construction.* Construction work on the spillway dam and powerhouse entered its final stage in the middle of September 1951, and on the other structures at the beginning of 1952 when the order of building the different structures was, to a large extent, governed by the time limits for installation of equipment, and by the readiness of the impounding structures for the filling of the storage reservoir. This responsible stage required precise organization of all building and erection-installation work in order to store all the spring water in the reservoir and to begin operation of the project in the spring of 1952. In this complex set of problems, special mention should be made of the following leading ones: completion of the concrete work on the dam and powerhouse, protection of the slopes, and the building of a drainage system in the dam, completion of work on the structures of the shipping canal, installation of equipment and erection of steel structures, completion of the headwork and the provision of a water supply for purposes of irrigation.

Concrete work on the spillway dam and powerhouse was conducted with a view to closing the bottom sluiceways at the beginning of January in order to keep work on these structures in advance of the filling of the storage reservoir. The most complicated of these jobs was the completion of the protected part of the upstream apron and the powerhouse



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and also the erection of the east-bank abutment wall. Depth pumps were used here for drainage on all jobs and were in action almost up to the very end of the work on the upstream apron and the placing of concrete in the lower lifts of the retaining wall. The work, which included hydro insulation and the placing of sandy loam, was completed in winter. Despite the unfavourable conditions these jobs were completed on schedule; the bottom sluiceways were closed on January 15 and filling of the reservoir was begun.

By the end of January 1952, concrete work on the pier blocks on the upstream side came to an end, and in the course of 10 days the trestle was moved downstream to a new position (Fig. 18). The placing of concrete was then continued in order to complete the head of the spillway and the middle pier blocks. As soon as a span was completed, installation of the gates was begun.

The situation was more complicated on the powerhouse and fishway jobs. Here, the pouring of concrete in the thin-walled flooring, piers, etc., was somewhat behind schedule,

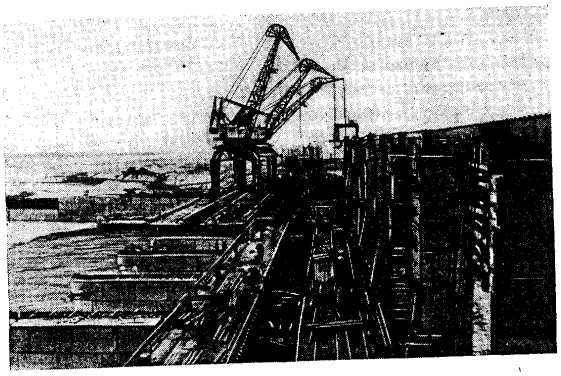

Fig. 18. Rails of steel trestle being shifted downstream to new position



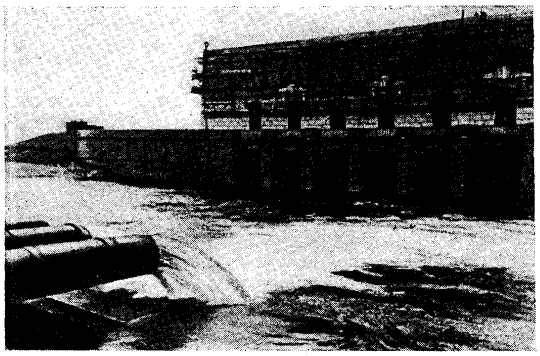

Fig. 19. Spring of 1952. Water being pumped to headworks of irrigation canal

thus delaying installation of hydraulic equipment in the powerhouse.

Large-scale assembly of the hydro sets and travelling cranes, in a specially equipped yard simultaneously with the main construction work, made it possible to complete the power station on time.

At the end of 1951 and during the first half of 1952 the upstream slope of the earth dam was covered with reinforced concrete slabs from 0.20 to 0.5 m thick. In its lower part, the upstream slope ends in a gravel and crushed-stone surcharge and at the crest merges into the reinforced concrete parapet. A railway line was run along the crest of the dam and was used for carrying the concrete mix in buckets on railway lorries hauled by gasoline locomotives.

On the sections of the earth dam that were farthest behind schedule (at its abutment with the spillway dam, and with the powerhouse), hydraulic-fill work, concrete reinforcing of the slopes, and driving of sheet piling were carried on simultaneously. There were periods when the top of the



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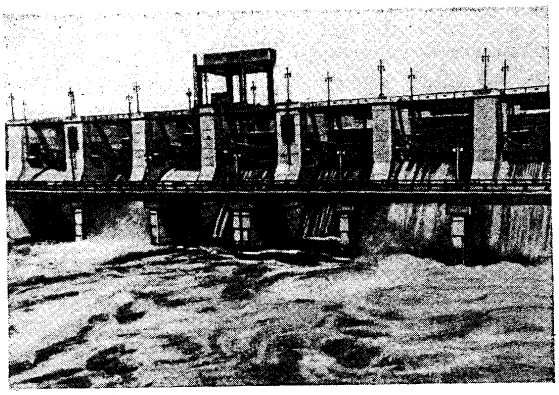

Fig. 20. High water of 1953 being passed over spillway dam

concrete facing was only 2 to 3 m above the rising water in the reservoir.

At the beginning of 1952, the shipping canal structures were not yet ready for filling. For this reason, the most urgent work was on the upstream lock guide and the installation of gates and valves in Lock No. 14. Erection work on Lock No. 15 also slightly lagged behind schedule. Fulfilment of a joint construction, installation, and erection work-schedule made it possible to complete the locks on time.

Trimming and planing work on the downstream canal was done in the winter months, and was to be completed by April 1 in order to ensure water for irrigation. The use of explosives, bulldozers and a specially built railway line along the canal helped to solve this problem. Up to the very last few days there remained a solid piece of ground on the intermediate channel for railway lines and motor roads. Four 3-cu m power shovels excavated more than 100,000 cu m of sandy loam soil, after which bulldozers took over along the whole job, and at the end of May the canal was filled with water. On June 1 the locks were filled and a locking test made. Gravity irrigation, especially in April and May of 1952, could not be achieved due to the low water level in the storage reservoir. The problem of supplying water for irrigation that year was solved by delivering it into the main Don canal with the aid of suction dredgers and pumping stations (Fig. 19).

Despite the early filling of the reservoir, the water level in it, in the spring of 1952, was below the rated level, but sufficient to ensure navigation throughout the season. Thus, all structures of the project were in operation in 1952 with a head 15 per cent below the rated level. The reservoir was filled to the required level during the high water of 1953, and 2 cu km of surplus water was discharged through the sluiceways of the spillway dam (Fig. 20) with the power station working at full capacity.



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CHAPTER THREE

## INDUSTRIAL PLANTS OF THE PROJECT

The main industrial plants of the project were the following: large-capacity concrete plants that supplied the necessary quantities of concrete mix; a large mechanized reinforcement-welding works for the manufacture of reinforcement trusses for the ferro-concrete structures; a plant for the production of reinforced concrete slab panels; and a woodworking factory for the manufacture of wooden form frames. The mechanized manufacture of reinforcement and forms made it possible to speed up preparatory work for the placing of concrete, and in this way to accelerate work on the different structures. Repair shops were built to maintain in working condition the large number of different building machines.

Plants handling the extraction and processing of materials (gravel borrow-pits, stone-crushing plants and filter-material borrow-pits) were directly subordinated to the Volgodonstroi.

*Concrete Plants.* The production of concrete was handled by five concrete plants characterized in Table 1.

These plants, after a tune-up period, began operation in the second quarter of 1951, and the total rated output of 7,680 cu m of concrete per 24-hour day fully satisfied all requirements. The rated output was topped by individual plants at different periods and reached a total of 8,975 cu m per 24 hours for the construction project as a whole.

The central group, which consisted of three concrete plants (one large plant and two smaller plants), was situated near



*Table 1*

| Name of concrete plant | Capacity in litres | Total number of mixers | Rated output in cu m | | Put into operation |
|---|---|---|---|---|---|
| | | | Daily | Monthly | |
| Large Concrete Plant (two-section) * . . . . | 2,400 | 8 | 4,110 | 82,000 | Sept. 1950 |
| Small Concrete Plant No. № 1 * (one-section) . . | 1,200 | 2 | 520 | 10,400 | May 1950 |
| Small Concrete Plant No. 2** (three-section) . . | 1,200 | 6 | 1,560 | 31,200 | April 1951 |
| Concrete Plant at Locks (two-section) ** . . . | 1,200 | 4 | 1,040 | 20,800 | April 1951 |
| Concrete Plant on West Bank . . . . . | 425 | 5 | 450 | 9,100 | May 1951 |
| *Total* . . . . . | | 25 | 7,680 | 153,500 | |

the spillway dam and powerhouse, and had rail lines for delivery of cement, crushed stone, and gravel from the storage yards. The concrete was delivered by rail and over hard-surface roads. (See layout of the concrete plants in Fig. 21.) The concrete plants near the locks and on the west bank also had railway lines and motor roads. The greater part of the concrete (up to 75 per cent) was produced by the highly-mechanized central group of plants, which included the large automatic plant.

The work of the concrete plants in 1951 is characterized by the data in Table 2.

* Automatic
** Semi-automatic



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*Table 2*

| Item | Large plant | No. 1 Small plant | No. 2 Small plant | Plant at locks |
|---|---|---|---|---|
| Delivery of concrete in 1951, thousands of cu m | 744.0 | 132 | 223 | 238 |
| Peak output: | | | | |
| per month, thousands of cu m | 84 | 17.7 | 39.4 | 29.1 |
| per 24-hour day, cu m | 4,007 | 898 | 2,108 | 1,713 |
| per hour, cu m | 271 | 43 | 134 | 80 |
| Days in operation | 343 | 335 | 205 | 231 |
| Shutdowns, % of total time | 42 | 41 | 40 | 30 |
| Breakdown of above according to causes: | | | | |
| technical trouble | 6 | 6 | 3 | 4 |
| interruptions in air and power supply | 3 | 3 | 3 | 1 |
| no demand for concrete | 28 | 29 | 33 | 24 |
| miscellaneous | 5 | 3 | 1 | 1 |
| Planned repairs, hours | 143 | 155 | 123 | — |

The large concrete plant consisted of two sections in the form of octahedral towers connected by a staircase (Fig. 22 and 23). In the upper department located above the bins were the drive units of the inclined aggregate conveyors, the intermediate conveyors, the cement elevator drive units, screw conveyors, distributors and the mechanization control panels of this department. The materials were discharged into the bins through a panel-controlled pivoting hopper. The capacity of the crushed-stone bin was 440 cu m, of the sand bin 220 cu m, and of the cement bin 280 tons. The bins were of steel and were equipped with tubular gratings for heating the aggregates. The proportioning department (outfitted with weight proportioners), the

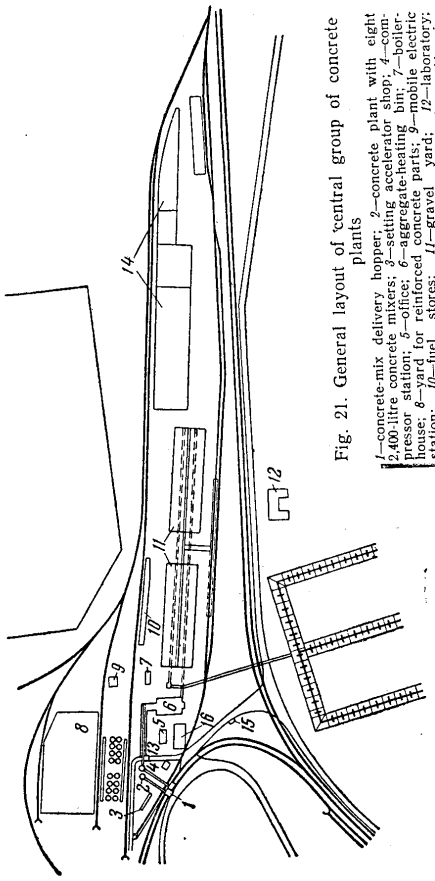


Fig. 21. General layout of central group of concrete plants

*1*—concrete-mix delivery hopper; *2*—concrete plant with eight 2,400-litre concrete mixers; *3*—setting accelerator shop; *4*—compressor station; *5*—office; *6*—aggregate-heating bin; *7*—boiler-house; *8*—yard for reinforced concrete parts; *9*—mobile electric station; *10*—fuel stores; *11*—gravel yard; *12*—laboratory; *13*—concrete plant with two 1,200-litre concrete mixers; *14*—reinforcement works; *15*—washing department; *16*—pumping station.





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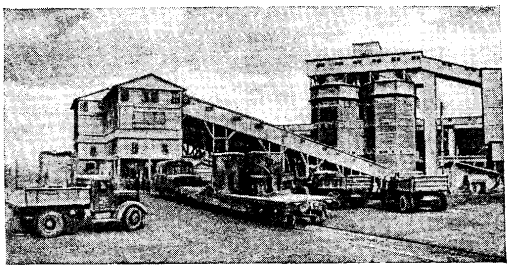

Fig. 22. General view of two-section concrete plant

water tank, the time relay and control panel were situated in the third storey. The proportion characteristics are given in Table 3.

*Table 3*

| Name of Operation | Proportion of cement | Proportion of water | Proportion of aggregates |
|---|---|---|---|
| Load, kg . . . . . | 900 | 550 | 1,100 |
| Self-weight, kg . . . . . | 1,400 | 1,100 | 1,200 |
| Value of scale division, kg | 50 and 2 | 50 and 2 | 50 and 2 |
| Weighing cycle, sec . . . . | 35 | 35 | 35 |
| Required pressure, atm . . | 7 | 7 | 7 |
| Consumption of air, cu m . | — | 10 per set | |
| Voltage in circuit, V . . . | 127 | 127 | 127 |
| Weighing control . . . . . | — | Automatic | |

The mixing department, each section of which had four concrete mixers, dry-mix hoppers and a pivoting hopper, was situated in the second storey.

The two sections of the plant were equipped with eight S-230 concrete mixers having the following specifications:



charging capacity 2,400 litres; drum speed 12.6 r. p. m.; motor type MA-145, 25 kW; air pressure 6 atm.

The ready-mix bin for receiving concrete from all four mixers, and the tension units of the conveyors leading to

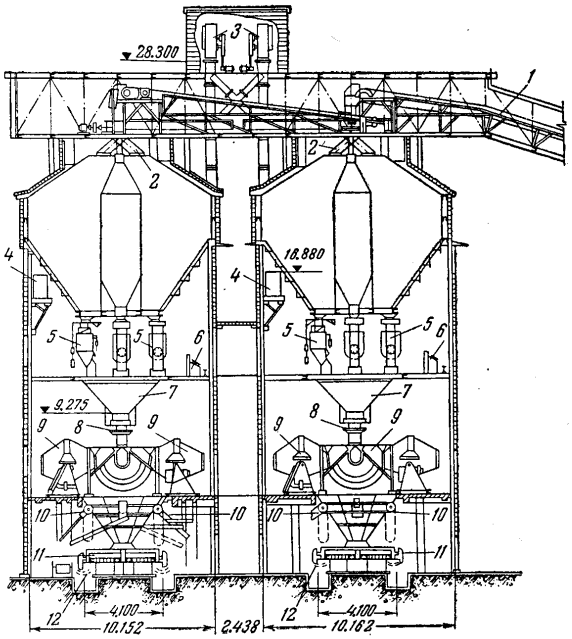


Fig. 23. Cross section of two-section concrete plant

*1*—belt conveyors for delivery of aggregates to bins (of belt width—800 mm); *2*—automatic pivoting hopper; *3*—cement-delivery elevators; *4*—water tank; *5*—automatic proportioners for mix constituents; *6*—control panel; *7*—collecting hopper for dry mix; *8*—automatic pivoting hopper for delivery of mix to concrete mixers; *9*—concrete mixer with pneumatic tipping drive; *10*—drop launder for washing concrete mixers; *11*—belt feeder; *12*—belt conveyor for delivery of concrete mix.



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the shipment bins were situated in the first storey. The plan provided for the production of up to four grades of concrete mix.

The flow sheet of the large automatic concrete plant was as follows:

The cement arrived by rail from the Volga, Novorossiisk and Bryansk cement plants, where it was produced according to the specifications of the Volgodonstroi, chiefly grade 400. The cement was received and stored in 16 siloes of 1,200-ton capacity each, equipped with screw conveyors and elevators. Transfer of the cement from the railway cars to the siloes and from them to the plant was centralized and automatic. The average supply of cement at the construction site in 1951 was close to 20,000 tons or equal to a fortnight's consumption.

In the main, two size-fractions of gravel and crushed stone, 10-40 mm and 40-120 mm, were used. The igneous gravel of the Gulkevich borrow-pit and the crushed limestone of the Zhirnovsk pit corresponded to the GOST (State All-Union Standards) requirements for hydraulic concrete. The gravel and crushed stone arrived by rail chiefly in dump cars, was unloaded into bins, and then delivered by belt conveyors to stacking machines for stacking in piles of more than 100,000 cu m. Fine-grained quartz sand (from alluvial deposits) with a fineness modulus of 1.2 to 1.6 was delivered by hydraulic dredgers from the excavation pit of the dam and powerhouse to a yard capable of holding 200,000 cu m. The sand and gravel were conveyed from the yards to the concrete plants by a system of belt conveyors (Fig. 24). A considerable number of operations in the storage and transportation of the sand and gravel to the plants were automatic.

The total length of the conveyors in the concrete plants was 3,426 m, and the distance covered by the crushed stone on the conveyor from the point of unloading to the plant was 1,046 m. The output capacity of the two conveyor belts (each 800 mm wide) running at a speed of 1.6 m per sec.

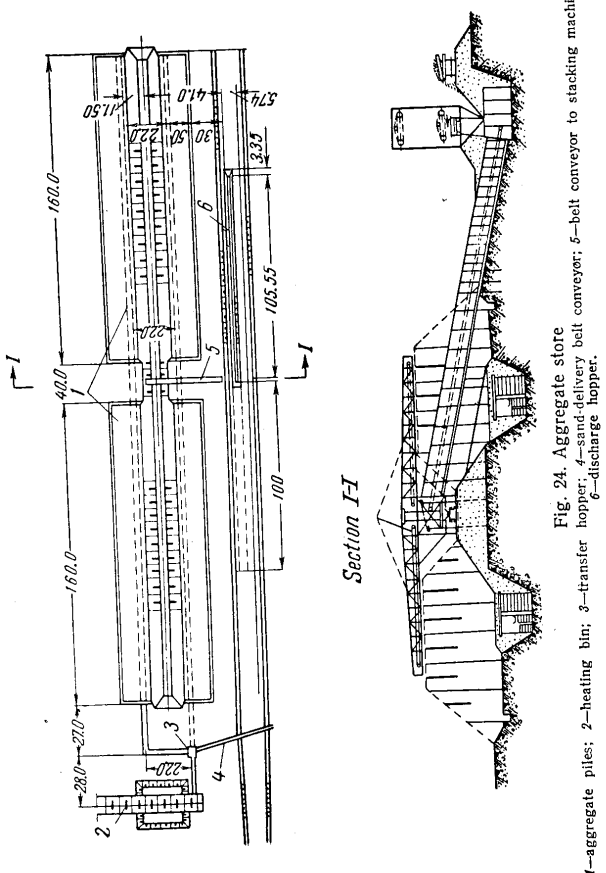


Fig. 24. Aggregate store
1—aggregate piles; 2—heating bin; 3—transfer hopper; 4—sand-delivery belt conveyor; 5—belt conveyor to stacking machine; 6—discharge hopper.



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was 520 cu m per hour, which ensured a normal delivery of crushed stone and sand.

The difficulties that arose were of a temporary nature and were due to underloading of the conveyors owing to faulty work of the feed chutes at the crushed stone yard, the bin feeders at the sand yard and the transfer assemblies.

In the transfer assemblies, the steel linings of the chutes lasted no more than a week. Engineers Tsurupa and Gusev suggested the use of removable steel screens as protective devices. This reduced shutdowns due to frequent changes of the lining.

Water supply was from deep-drainage wells in the pit of the spillway dam, whence water was pumped to two concrete tanks, each with a capacity of 200 cu m, and from them delivered by a pumping station to the tanks of the concrete plants. A pump with special appliances was used for delivering hot water in winter and for adding the softening agent in summer. The water passing through this device received the required amount of softener.

At the concrete plant, the cement and aggregates were received in bins, each with a capacity sufficient for two hours of continuous work; from there they entered the automatic weight proportioners, and finally the concrete mixers.

The automatic arrangement of the weight proportioners was not perfect and required constant observation. As the personnel operating the proportioners gained experience, their work became more efficient, as may be seen from the check-up data in Table 4.

The concrete mixers unloaded into bins; the mix was then conveyed by a belt conveyor into the delivery department which had 16 bins, each with a capacity of 9 cu m. It was considered normal for one section of the large plant to load 12 to 13 trains with concrete per hour; at times, the number of trains rose to 15 and 16.

The technological equipment and pneumatic tools were supplied with air from the compressor department which had three compressors of 20 cu m per minute and two compressors of 10 cu m per minute each. In 1951, the air consumption per cubic metre of concrete was approximately 10 cu m.



*Table 4*

| Months of 1951 | Number of tests taken | Number of overweights | Number of underweights | Average overconsumption of cement in per cent |
|---|---|---|---|---|
| June | 92 | 650 | 276 | 1.30 |
| July | 834 | 483 | 351 | 0.80 |
| August | 783 | 517 | 266 | 0.14 |
| September | 827 | 526 | 301 | 0.57 |
| October | 825 | 156 | 369 | 0.34 |
| November | 830 | 484 | 346 | 0.00 |
| December | 795 | 607 | 188 | 0.32 |

G. P. Sikharulidze, control panel operator of the large automatic plant, and E. V. Lemeshko, control panel operator of the small automatic plant, made a careful idle-run check of all machines at the beginning of each shift, and immediately repaired anything they found out of order. The automatic proportioning scales, the pneumatic cylinders and electric circuits were adjusted by the time they received the control room engineer's start-up signal.

Due to the effective preparatory work, the plant began operating at full output as soon as the engineer gave the order to the control panel operators, whose duty it was to ensure the proper sequence and precision of operations.

The water tank and the bins for cement, sand, crushed stone or gravel were always full. The water was delivered first in order to free the pivoting hopper for the next concrete mixer. The operators took prompt measures in handling breakdowns.

Sikharulidze, working in the second section of the large plant, put out 46,913 cu m of concrete in the third quarter of 1951 with a peak monthly output of 17,749 cu m, or



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1,207 cu m per 24-hour workday, and up to 149 cu m per hour. He succeeded in reducing the batch cycle from 186 seconds to 166 seconds (without impairing the quality of the concrete) by utilizing every moment of the workday and by skillful operation of the machines. Sikharulidze achieved a quarter-year production of concrete that was 6,060 cu m above that of the other operators.

Operator Lemeshko, working at the small plant equipped with two concrete mixers of 1,200 litres each, achieved the following outstanding results: quarterly output—17,597 cu m; monthly output—6,075 cu m; output per shift—441 cu m, and per hour—48 cu m. During his shift, Lemeshko exceeded the output of the other operators of this plant by 1,671 cu m per month, and 2,331 cu m each quarter.

The manufacture of concrete in winter conditions required tanks of 200-cu m capacity for heating water, and special 800-cu m bins for heating the aggregates (Fig. 25), the rooms of the plant, and the conveyor ways.

Steam was supplied from a temporary boiler room where use was made of old locomotives with a total heating area

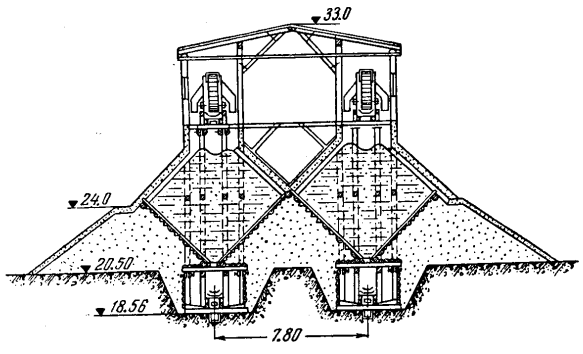


Fig. 25. Cross section of aggregate heating bins



of 960 sq. m in the boilers. The fuel consumption in terms of coal equivalent per cubic metre of concrete in 1951 reached an average of 3.6 kg with 12.7 kg in December and a peak consumption in January of 21.5 kg. The number of workers engaged in winter work came to about 17 per cent of the total personnel of the plants. The production cost of concrete manufactured in winter rose approximately 5 per cent.

The plants were supplied with power from the central substation of the construction site through local 2,500-kVA transformer substations at the plants. The total installed capacity of the three plants was 3,631 kW; and the annual consumption of electricity 5,067,000 kWh, or 4.6 kWh per cubic metre of concrete.

The concrete mix for the basic structures of the project had a plasticity of 6 to 8 cm as it left the mixer. This was due to peculiarities of technology and the high rate at which the concrete was placed. Since the large plant had a single receiving bin and delivery bin, only plastic mixes could be handled. The production of concrete with a settling of the cone of 3 to 4 cm usually led to bridging at the discharge openings of the bins, thus causing delays in delivery. Even the use of buckets with conical walls for transporting the concrete did not ensure rapid discharge of a harsh concrete mix. The vibration chutes, which were 250 mm in diameter and up to 25 m in length, operated continuously only with plastic mixes. In addition, the selection of plastic mixes proved correct for concreting close-mesh reinforcement blocks.

The average consumption of cement per cubic metre of concrete amounted to 306 kg, while laboratory specifications called for 299 kg. Distribution as to grade is given in Table 5.

*Reinforcement-Welding Works.* By September 1950, a Central Reinforcement Works located 1.6 km from the spillway dam and powerhouse, and with a 24-hour capacity of up to 200 tons of reinforcement, was built to supply the



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*Table 5*

| Grade of Concrete | Volume of concrete placed in thousands of cu m | Consumption of cement, in kg per cu m | Water-cement ratio |
|---|---|---|---|
| 170V4 . . . . | 639 | 297 | 0.645 |
| 170V4M . . . | 466 | 265 | 0.65 |
| 200V4 . . . . | 67 | 320 | 0.60 |
| 200V4M100 . . | 362 | 290 | 0.58 |
| 200V8 . . . . | 79 | 332 | 0.58 |
| 250V4M100 . . | 84 | 311 | 0.50 |
| 300V4M150 . . | 235 | 360 | 0.45 |
| | 1,932 | 299 | |

ferro-concrete structures of the project with reinforcement. At the end of 1950, an independent reinforcement yard was established near the locks to supply the canal structures with reinforcing steel.

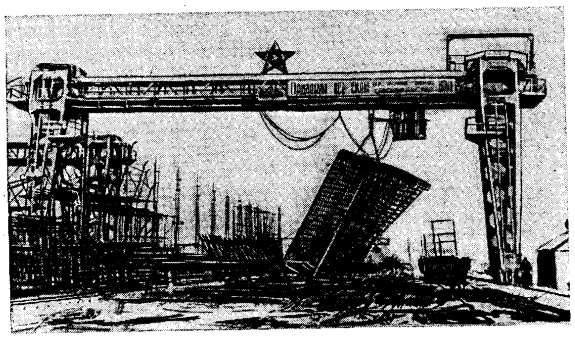

Fig. 26. Yard of reinforcement-welding works



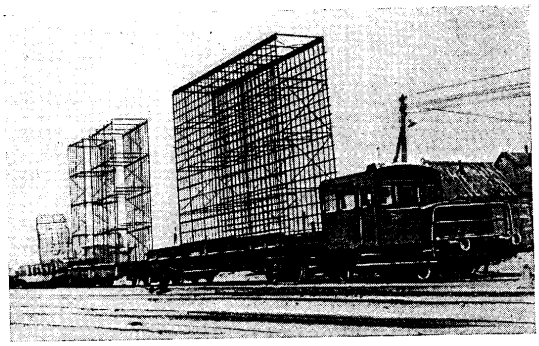

Fig. 27. Reinforcement trusses being transported on railway trucks

The Central Reinforcement Works (Fig. 26) was reconstructed and expanded at the end of 1950, when it delivered 300 tons of reinforcement every 24 hours. The reinforcement works and the erecting of reinforcement frames were in a separate specialized district. The works was linked with the different sections of the project by railway lines and motor roads that permitted transportation of ferro-structures 22 m in length, and up to 8 m in width and height (Fig. 27).

The Central Reinforcement Works had the following departments: warehouse for metal, principal manufacturing and assembly departments, department for the manufacture of reinforcement for slab panels, intermediate warehouse of semi-finished structural members, a finished-goods storehouse, auxiliary workshops (a shop for the manufacture of electrodes, an electric shop, machine shop, and a shop for the production of patterns and jigs).

The reinforcement works was equipped with the latest machines for contact-joint electric welding which permitted



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the welding of 6,000 joints per 24 hours; it also had powerful bending machines capable of bending over 300 tons of wire rod every 24 hours, and automatic machines for straightening small-diameter reinforcing steel.

Nine different-type cranes of varying hoisting capacity handled the movement of semi-finished and finished units within the works, and also the loading of such for outside transportation.

The plant had its own 1,680-kVA step-down substation that ensured stable operation of the electric-welding equipment. Air was supplied from a stationary compressor unit with a capacity of 10 cu m per hr. Water was supplied from the town water main, and there was an additional emergency reservoir of 96 cu m and a fire tank of 10 cu m together with a pumping unit.

Table 6 gives a list and brief description of the principal machines of the works.

In the manufacture of reinforcement use was made of high-speed flow methods with all operations mechanized. The flow sheet included the following consecutively performed operations: the reinforcement steel, after straightening and cleaning of the ends, was delivered in the form of individual rods of various lengths by roller conveyors to the contact-joint machine that welded the joints. The welding machines were specialized. Automatic RKSM-200MA machines welded steel 70 to 80 mm in diameter, MSM-150 machines welded 60 to 70 mm steel, SKM-100 machines handled 40 to 50 mm steel, and ASIF-75 machines welded 20 to 30 mm steel; all these machines ensured both high output and high quality in the welding work. MTM-5 machines were used for spot welding of reinforcement for slab panels.

After the joint was welded, the long rod was conveyed to the cutting machines by roller conveyors. Here it was cut and marked. Rods up to 40 mm in diameter were cut by S-150 machines; diameters above that were handled by oxy-acetylene units.



*Table 6*

| Name of machine | Type | Quantity | Greatest tolerance of reinforcement, mm | Efficiency | | Notes |
|---|---|---|---|---|---|---|
| | | | | Rated | Actual Peak | |
| Reinforcement cutting machines* | S-150 | 10 | 32/40 | 16.5 | 18 | Dia up to 40 mm |
| | S-146 | 16 | 32/40 | 7.5 | 8.5 | Ditto |
| Bending machines | S-266 | 6 | 90 | 16.2 | 18 | Dia 70 mm |
| Ditto | | | | | | Dia 80 mm |
| | | | | | | 24 tons per shift |
| Automatic machines for straightening and cutting wire rod | S-234 | 7 | 5-12 | 1.6 | 5 | |
| | NA-135 | 1 | 60 | 20.6 | 30 | |
| Press-shears | | 2 | 4 | 3,000 | 3,000 | |
| Machines for spot welding** | MTM-50 | 4 | 28 | 30 | 30 | |
| Contact-welding machines | ASIF-75 | 2 | 70 | 10 | 10 | |
| Ditto | SKN-100 | 2 | 85 | 8 | 9 | Dia 80 mm |
| Ditto | RSKN-200 | 5 | 25-50 | 12 | 12 | Dia 50 mm |
| Ditto | MSN-150 | 2 | 85 | 14 | 15 | Dia 80 mm |
| Ditto | Federal 250 | | | | | |

* The efficiency of the cutting and bending machines is given in tons per shift.
** The same for contact-welding machines is given in weldings per hour.



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The rods thus obtained (each of a given length) were conveyed to the bending machines which produced finished parts of rod reinforcement. Rods 40 mm in diameter were bent on S-146 machines, and those of greater diameter on S-266 machines.

The finished parts were delivered to slips, where the manufacture of reinforcement structures by electric welding was done in jigs. The hoisting and moving of reinforcement trusses during production, and the loading of finished reinforcement trusses was handled by 10- and 5-ton gantry cranes, crawler cranes and T-72 cranes.

The manufacture of reinforcement by year is given in Table 7.

*Table 7*

| Place of Manufacture | Amount of reinforcement manufactured in tons | | | |
|---|---|---|---|---|
| | 1950 | 1951 | 1952 | Total |
| Central Reinforcement Works | 8,846 | 61,552 | 8,159 | 78,557 |
| Other reinforcement shops . | 2,170 | 9,264 | 8,185 | 19,619 |
| | 11,016 | 70,816 | 16,344 | 98,176 |

The figures in the table show that the actual average consumption of reinforcement per cubic metre of concrete placed was approximately 50 kg as against about 47 called for by the plan. The increased consumption of reinforcing steel was due to additional steel being used on covered butt joints, and partly to steel used for the holding of the forms; to losses (not taken account of in the plan) in the preparation of test samples for checking the welded joints, and also in cutting and melting when jointing.

In order to cut down the quantity of rod reinforcement (since it complicated the mechanization of erection work)



the builders (engineers A. A. Shcherbinin, A. A. Tikhomirov, I. S. Kitashev, and others) together with the designers (engineers L. V. Khromova, U. P. Kuznetsov, V. S. Panfilov, and others) reconsidered the drawings in the course of the work, and made greater use of large-size reinforcement trusses and blocks. The weight of each reinforcement truss was limited by the lifting capacity of the erection cranes.

Labour productivity rose as technology in the manufacture of welded structures improved and the machines reached their rated outputs. It was also influenced by the growing skill of the workers. The average output per shift of one worker manufacturing welded structures (all auxiliary operations on the project included) was 265 kg; output at the Central Reinforcement Works during 1951 was 320 kg, and in August 1951 it reached 423 kg.

Among the best workers in the division of reinforcement-welding work were Heroes of Socialist Labour A. A. Shcherbinin, who headed the work, Ulesov, an electric welder, and Polyakov and Boldyrev, young electric welders that attained success in high-speed welding.

*The Reinforced Concrete Slab Panel Plant.* A considerable part of the surfaces of the spillway dam, the powerhouse, and the canal locks were to be covered with special reinforced concrete slab panels. Slab panels gave the structure a more durable surface, an architectural finish, and at the same time served as forms during concreting.

Slab panels were used to cover a total of about 106,000 sq. m of surface, including about 70,000 sq. m on the spillway dam and powerhouse, and about 36,000 sq. m on the canal locks.

A special plant with all production operations mechanized was built to manufacture reinforced concrete slab panels.

A special-type concrete mix had to be used to meet the high-durability requirements of the panels. A high-grade puzzolan-Portland cement was used for this concrete mix. The panels were formed on a vibrating table, followed



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by steaming in a moist atmosphere. Two types of slabs were produced: flat and curvilinear.

The moulds for manufacturing the slabs were chiefly of the metal type, but some of them were wooden, lined with steel.

The slab panels were reinforced by a rigid, spaced frame of flat trusses (Fig. 28) and rod elements in the form of coils emerging from the body of the panels and serving as anchors for holding the panels to the main reinforcing block and also for attaching erection braces and special fasteners designed to hold the slab in place during concreting of the block.

The slab panel plant was situated next to the central group of concrete plants; it had its own management and was connected by rail with the different construction sites. It had the following departments: a reinforcement department with a floor area of 1,000 sq. m, a mould department (1,200 sq. m), a concreting department (400 sq. m), a steaming department (700 sq. m), a purifying chamber (120 sq. m), a department for preliminary curing (700 sq. m), stores for finished goods (1,100 sq. m), aggregate stores (350 sq. m), a concrete-mixing assembly (200 sq. m), a cement store (100 sq. m), and a boiler room with 6 boilers, each with approximately 28 sq. m of heating surface.

The plant began operation in May 1951 and increased output gradually, achieving in December 1951 a peak production of 4,220 slabs with a total area of 19,251 sq. m (or 1,857 cu m in terms of volume).

In addition to slab panels, it also manufactured a number of other items, and from the beginning of 1952 the production of architectural parts made of white cement and marble dust for facing the structures of the project was handled mostly at this plant. The total output of the plant may be broken down as follows:

| | Quantity | Volume in cu m |
|---|---|---|
| Slab panels | 21,402 | 9,405 (or 106,000 sq. m) |
| Parapets | 1,449 | 922 |
| Architectural parts | 11,496 | 912 |
| Dam beams | 14,686 | 623 |



A second plant was set up on the west bank designed to manufacture chiefly round reinforced concrete piping for the drainage system of the earth dam, reinforced concrete

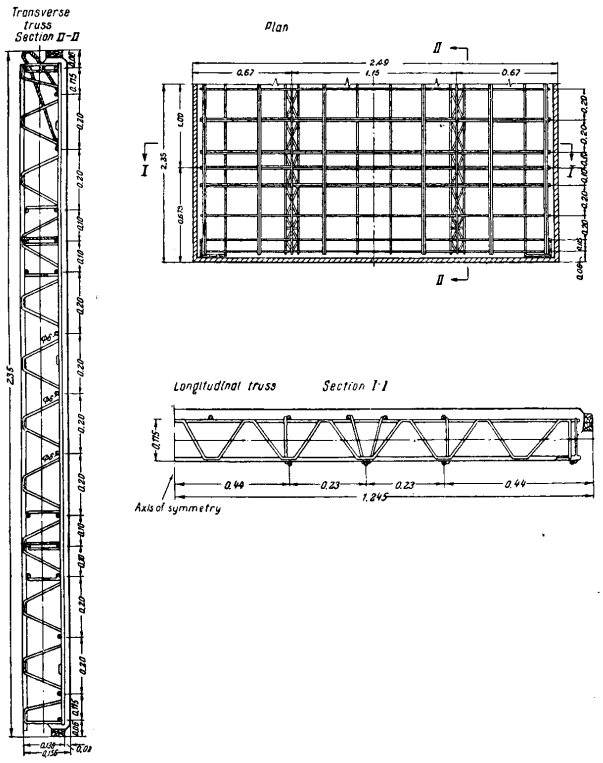


Fig. 28. Reinforcement of a flat slab panel





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tunnel and channel rings for the cables of the substations, and certain other items. This plant turned out 14,900 linear metres (or 5,791 cu m) of various-diameter round pipes and 1,380 cu m of other parts, including rings for cable channels.

*Woodworking Factory.* The large number of various forms, door frames, window sashes and many other structural parts, in addition to the manufacture of parts for the interior furnishing of the buildings, necessitated the construction of a woodworking factory, which would not only manufacture wooden structural parts, but would also produce sawn goods, beams, and railway sleepers from round timber.

The factory had the following production departments: a sawmill department with a 24-hour output of 150 cu m of sawn timber; a form department with 13 machines capable of turning out up to 800 cu m of form panels and 40 cu m of planed boards every 24 hours; a joinery shop consisting of three sections (preparatory, assembly, and finishing) and equipped with 20 machines capable of producing 100 sq. m of window sashes, doors, and door frames every 24 hours; a steam-boiler department with five drying chambers, each with a total capacity of up to 300 cu m of sawn timber per month; and a machine shop together with a forge shop for repairing machines and equipment and for the manufacture of various types of forgings.

During the period of construction, the factory turned out a total of 128,000 sq. m of forms, 35,000 sq. m of window sashes and door frames, in addition to 67,000 cu m of sawn timber. Aside from this, the factory produced doors, windows, and other items made of oak for the service buildings of the hydraulic structures. This work was supervised by the director of the factory, engineer V. N. Zinukov.

*Machine-Repair Shops.* The large number of building machines, motor vehicles, and the great quantity of various other equipment at the construction site urgently required shops for on-the-spot repair work.



Daily maintenance of the building machinery and medium maintenance of the simpler types of machines was handled by the repair shops of each construction district. Medium maintenance and major overhauling of the greater part of the machinery was carried out by the several central repair works of the project and also partly at different factories.

Table 8 gives the number of district repair shops and the equipment at their disposal during different periods.

*Table 8*

| Item | 1949 | 1950 | 1951 | 1952 (1st half) |
|---|---|---|---|---|
| Number of shops . . . . . | 3 | 11 | 40 | 35 |
| Total number of metal-working machines in them | 7 | 33 | 169 | 175 |
| Number of principal machines . . . . . | 4 | 20 | 128 | 134 |

The number of metal-working machines in the different repair shops is given in Table 9.

*Table 9*

| Name of Repair Works | 1951 | | 1952 | |
|---|---|---|---|---|
| | Total number of machines | Lathes | Total number of machines | Lathes |
| Central Machine-Repair Works . . . . | 55 | 26 | 68 | 27 |
| Auto-Repair Works . . . | 36 | 16 | 42 | 16 |
| Machine-Repair Works | 26 | 8 | 34 | 9 |
| *Total* . . . . . | 117 | 50 | 144 | 52 |



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The Central Repair Works had the following departments: foundry, forge shop, machine shop, steel structure department situated in the open, lathe-repair shop equipped with stands for cold and hot running in of diesel engines and capable of overhauling 18 S-80 tractors per month; open-air department for handling building machinery repairs; and an oxygen station with an output capacity of 30 cu m of oxygen per hour.

Up until 1952, the repair works confined itself to repairing tractors and the manufacture of spare parts for the different construction districts. It also manufactured steel structures for hydraulic and non-standard equipment, and forged pieces.

A permanent-type auto-repair works was built at the end of 1950 and was designed to overhaul 300 motor vehicles per year. It had the following sections: machine shop, motor shop, unit assembly department, forge and heat treatment shop, assembly shop, body department, repair shop, electric department, and testing station.

The manufacture and repair of electrical equipment, transformers and electric motors was handled by the electric shops of each power district and also partly at different factories by special order. A special repair works was built for the suction dredgers and other similar equipment. There were also district and section shops that came under the Hydraulic Mechanization Management.

Large-size assembling of technological equipment and of gates and steel structures of the main sections of the project was carried out on assembly grounds supplied with specially-equipped stands, hoisting and transportation facilities, machine shops, and electric repair shops, which were likewise under the supervision of the contractors.

The construction work on the storehouses and production buildings totalled 450,000 cu m. It should also be mentioned that in the temporary settlements of the builders, nearly 180,000 sq. m of dwelling space and up to 340,000 cu m of buildings for community use was built.

## CHAPTER FOUR

## TRANSPORTATION, POWER SUPPLY, AND COMMUNICATIONS

*Transportation.* Over 10 million tons of building materials, equipment, and other freight had to be delivered to the construction site. Of these, 5,900,000 tons were required in 1951. The transportation of such huge quantities of material could not be handled without railways, which took care of 86 per cent of all the freight.

For this purpose, two railway lines were built from the nearest stations of the trunk line to the construction sites on the west and east banks of the river. These lines were connected by a provisional 20-kilometre railway for operation during the construction period. This line passed through the entire construction grounds and crossed the Don over a temporary high-water railway bridge 590 m long. It ensured constant communication between the banks and enabled delivery, from both directions, of freight to the various points of the job, as required.

Three railway stations, "West Bank," "Concrete Plant," and "Locks," were built at the construction site to facilitate distribution and unloading of incoming rail freight. From these stations, a network of interior railway lines extended out to all the large auxiliary works, the Don River wharf, and the building sites. These lines had 186 switches and measured 120 km in length.

In 1951, 28 locomotives, 120 self-tipping railway trucks, and a large number of ordinary cars and trucks were in



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use in addition to the cars and trucks of the Ministry of Railways. Over 1,000 railway cars arrived at the construction site every 24 hours.

Besides the railway lines, there was a network of motor roads connecting the auxiliary works with the settlements and construction sites. A bridge on metal pontoons was thrown across the Don for motor and foot traffic. The main roads were of the hard-surface type.

During the period of most intense work, the motor pool of the project consisted of 1,324 motor vehicles, including 405 MAZ-205 tip lorries and 561 ZIS-585 tip lorries.

During the construction period, motor vehicles hauled 38,400,000 tons of various freight, including 19,400,000 tons in 1951 alone. The total motor-vehicle haulage amounted to 136 million ton-kilometres, which included the following: 11,000,000 tons of earth, 1,450,000 tons of concrete mix, 4,200,000 tons of sand, crushed stone, rock, and gravel, 1,300,000 tons of timber and nearly 100 million bricks.

In motor transportation, a decisive role was played by the 5-ton MAZ-205 tip lorries, which handled more than one half of the total freight. In 1951, the average annual haul of a MAZ-205 lorry amounted to 66,000 tons, or 155,000 ton-kilometres, that of a ZIS-585 lorry was 31,000 tons, or 100,000 ton-kilometres. The MAZ-205 lorries were used on 4th class roads with big grades in the loaded direction.

New 12-ton YAZ-210-E and 25-ton MAZ-525 lorries were employed mainly in the borrow-pits. YAZ-210-E lorries showed very good performance, and it may be said that the successful and widespread utilization of heavy-duty motor vehicles in hydro construction work is a problem of the nearest future.

Railway transportation was supplemented by river transportation on the Don and the Northern Donets. The project had six tug boats, 400 HP each, 22 steel barges of 800 tons pay load each, and 20 motor boats. In addition, a considerable part of the freight was transported by vessels belonging to the Ministry of Inland Water Transport. Temporary wharves and warehouses were set up at the construction site for freight (mostly rock, gravel, coal, brick, and oil products) arriving by water. River transportation accounted for 14 per cent of all the freight delivered to the construction site.



*Electric Power Supply.* The importance of an efficient power supply is evident if we take into consideration the vast amount of building machinery, the machine tools in the various industrial and production establishments, the drainage equipment, and also the extensive construction grounds and workers' towns that require electric lighting. Special attention was paid to this question from the very beginning.

Two 5,000-kW power trains were put into service in 1949, one at the end of June, and the other in September. By September 1950, a 110-kV transmission line 150 km in length was built to connect the project with the Rostov power system; a central step-down substation with two transformers (15,000 and 20,000 kVA) was also put into operation.

During this same period, an increased number of tower-type and transportable transformer substations were erected to cope with the growing requirements of the construction districts. In all, there were 138 transformer substations with 141 transformers possessing a total capacity of 36,420 kVA. There were nearly 460 km of high-voltage overhead and underground cable lines, and about 450 km of low-voltage distribution networks.

During the period of greatest activity, the total installed capacity of the power consumers reached 133,333 kW, and was distributed as follows: suction dredgers and pumping stations 85,000 kW, welding equipment 9,000 kW, 1,780 induction motors of various capacities—a total of 28,740 kW, 86 direct-current motors—5,170 kW, about 2,200 vibrator machines—1,300 kW, lighting of up to 20,000 points—4,150 kW. The total amount of electric power consumed



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during the period of construction exceeded 330 million kWh, of which 212 million kWh was consumed in 1951.

The actual peak load was 62,000 kW, and the maximum consumption per month about 31 million kWh. The power requirements of various consumers were distributed as follows: hydraulic machinery—58.2 per cent, manufacture and placing of concrete—3.2 per cent, manufacture of reinforcement—1.9 per cent, excavators—6 per cent, lighting—7.7 per cent, machine-repair shops, drainage, and other consumers—23 per cent.

It should be noted that in 1951, the total capacity of all motors and machines in operation at the construction site amounted to 230,000 kW, of which electric machinery accounted for 133,300 kW, or 60 per cent. The power output of the electric motors provided with semi-automatic control was 47,600 kW, and of those with full-automatic control 3,500 kW. These figures show that electricity played a decisive role in mechanization of work.

The widespread application of semi-automatic and full-automatic control of motors was a big step forward in efficiency.

*Temporary Communications.* The early organization of an efficient system of telephone and radio communication that was established between the different sections of the project played a significant part in organizing the work, if one considers the large number of jobs and the extent of the territory under construction.

Throughout the period of construction, communication between different jobs at the construction site and also between the site and the outside (the towns of Rostov, Kalach, and others) was maintained chiefly over a dense network of telephone lines. During this period, close to 185 km of telephone-pole communication lines were established with 2,400 km of wire strung. Approximately 100 km of various-capacity aerial and underground cable was installed. This amounts to over 6,000 kilometre-strands. Over 30 telephone centrals (from 30 to 500 numbers each) were established with a total operating capacity of 2,700 numbers.

In addition, wide use was made of short-wave radio sets of the "Urozhai" type, some 60 of which were set up.

Broadcasting was also used extensively at the site. Radio stations with networks of loud-speakers at the headquarters of the different jobs were used for broadcasting orders and instructions. Different types of radio apparatus were installed at 1,700 points. Using loud-speakers it was possible to call to the telephone persons located directly on the job.

Electric clocks were used at many places to ensure better organization of hour schedules. There were six electric clock units with a total of 200 electric clocks.



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CHAPTER FIVE

## COFFERDAMS, DRAINAGE AND THE CLOSING OF THE DON RIVER CHANNEL

*Cofferdam.* The cofferdam that protected the excavation pit of the spillway dam and powerhouse from the Don River on three sides was three kilometres in length. The form of a typical cross section of the cofferdam was trapezoidal with a top width of 20 and slopes of 1:3. Only where the dam crossed Lake Susarevo and plastic silt-type loam was met in the base was the upstream slope of the dam given a batter of 1:20 to allow free flowing of the fill sand slurry. The cofferdam was built before the high water of 1950 by sluicing into place sand from the excavation pit. During the filling of the cofferdam, the sandy loam placed in the base of the dam where it crosses Lake Susarevo began to squeeze out. In order to stop this, the downstream slope was made more gradual with a batter of approximately 1:10. Hydraulic filling accounted for 2,500,000 cu m of earth moved; in addition, 1,000,000 cu m were dumped. The cofferdam made it possible to bring up rail lines and motor roads, lay out warehouses for the basic equipment and yards for assembling and erecting the portal cranes and the steel concrete-delivery trestle.

On the river side, the slopes of the cofferdam were reinforced over an area of 44,000 sq. m with fascine mattresses surcharged with rock, and over an area of 56,000 sq. m with dumped rock and rock in wattle cribs. The dam had a rock-protected headwater pier for directing the flow of water from the east-bank flood plain, and was designed to prevent flooding by high water with a probability of repetition of 1 per cent in the case of the crest having a safety height above the water level of the order of 1.0 m.

*Drainage.* In order to protect the excavation from ground water, 121 wells (Fig. 29), 350-470 mm in diameter each, were sunk along the perimeter of the pit to depths up to 40 m. At first the wells were sunk hydraulically with the aid of high wooden boring derricks and then with drilling rig of the BU-20-2 type adapted for the sinking of deep wells. Each such well was equipped with vertical ATN-10A

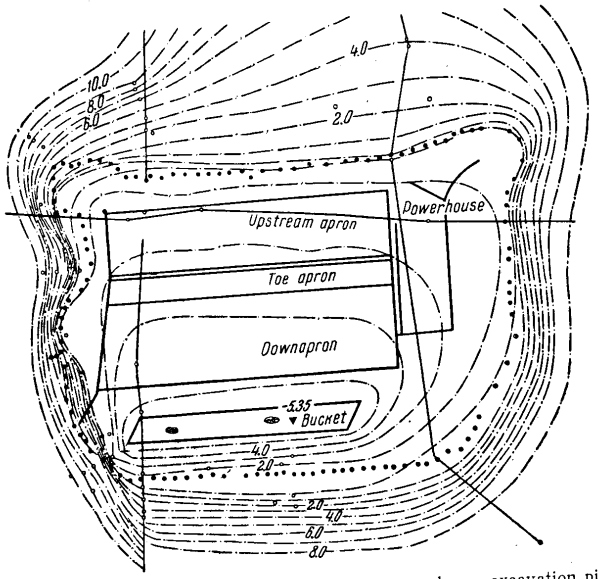


Fig. 29. Contour of water table of dam and powerhouse excavation pit





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pumps, each of which had a capacity of 75 cu m per hr. The pumps were supplied with 22-kW motors (1,470 r.p.m. at a full head of 45 m). An assembled pump weighed 2.7 tons.

Mobile well-points or additional wells equipped with ATN-10A pumps were placed in the pit at various low points to supplement the contour pumping. A total of 140 ATN-10A pumps were installed, and 16 to 18 sets of mobile well-points were in operation at one time. The output of the depth pumps and well-points reached a maximum intensity of 2.5 cu m per sec.

*Passing the Don River Discharge.* During the construction period of 1950 and 1951, the discharge was passed through the natural channel of the river, narrowed by the cofferdam; from September 1951 to the spring of 1952 it was passed through the bottom sluiceways in the spillway dam, and from the spring of 1952, through the turbines of the powerhouse with excess water (after the filling of the reservoir to the required height) passed through the spillway-dam sluices in accordance with regular operation procedure.

The spring water of 1950 was not very high, and since the flood plain of the Don was hardly at all covered with water, the cofferdam and drainage systems that year were tested under a slight load.

The spring high water of 1951 was above average and coincided with intense reinforced concrete work in the pit of the dam and powerhouse. The entire flood plain of the Don was covered with water, and the excavation pit surrounded by the cofferdam became a peninsula. During this period, concrete was being placed in the blocks at the base of the dam. The foundation of the dam was excavated below the level of the river channel, and the highest head on the cofferdam at certain points reached 22 m. At these points, a layer filter of large-grained sand and gravel (each layer 0.5 m in thickness) was built on the downstream slope to meet the spring high water.

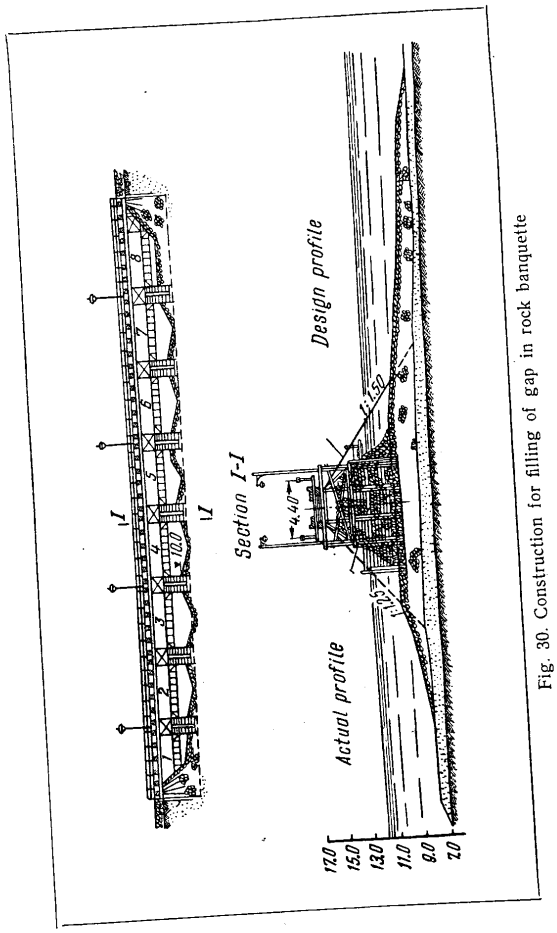


Fig. 30. Construction for filling of gap in rock banquette



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At this time, work was begun on the earth dam on the west flood plain of the river. The west flood plain of the Don was almost completely dammed up with the overburden from the dam pit and with spoil placed in the main body of the dam. In this way, the entire discharge of the Don was directed into the main narrowed channel of the river. The velocity of the flow in this channel reached 1.8 to 2.0 m per sec. at this period. Thanks to the protection-facing of the cofferdam and irreproachable operation of the depth drainage system, the excavation pit was kept dry and concrete was placed round the clock without a stop.

*Closing the Don River Channel.* One of the main stages in the construction of the Tsimlyanskaya hydro project was the closing, in September 1951, of the main channel of the Don with a rock banquette and the transfer of the discharge to the concrete spillway dam.

The 360 m long rock-fill banquette that was thrown across the river channel of the Don had a trapezoidal cross section with a top width of 2.0 to 4.0 m and a height of 4.0 to 8.5 m.

A gap (100 m wide at the top and 80 m wide at the bottom) located near the west bank of the river was left open in the banquette to pass the discharge of the Don. In order to prevent erosion of the sand river bottom during the passage of the discharge through the gap, a mattress in the form of a gravel and crushed-stone fill, 85 m in width and 0.75 m thick, surcharged with a 0.5-m layer of rock, was placed under the banquette. The mattress and banquette were made by dumping gravel and rock into the river from barges, use being made of floating cranes with grabs.

A bridge supported on wooden cribwork (Fig. 30) was built across the gap left in the banquette. The supports were assembled ashore and then put into place on the water with the aid of winches and cutters. The spans of the bridge were made of two pairs of No. 36 (U.S.S.R. Standard) I-beams, on which were placed wooden crosspieces made of beams 25 cm in diameter. Log panels for the wheels of the vehi-

Fig. 31. Tip lorries keep up a continuous flow of rock to close gap

cles were then laid on the crosspieces with a clearance (the length of the bridge) of 1.3 m between the panels. This was necessary to facilitate dumping of rock from tip lorries at any point on the bridge without turning the vehicle.

Piles of rock needed for filling the gap were prepared along the west bank of the Don River and the adjacent railway line. A special 2-km circular motor road with a crushed-stone surface was also built for this purpose (Fig. 31). As work proceeded on the rock banquette, spoil was pumped into place on both sides of the river with a free gap left for passing the discharge.

After preparing the concrete structures for passage of the river discharge, filling of the excavation pit of the spillway dam and the powerhouse with water was begun on September 16, through a feeder canal by dismantling the upstream cofferdam and by passing a part of the Don discharge through the bottom sluiceways of the spillway dam.



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The last task before closing the gap in the rock banquette in the Don River channel was to dismantle the downstream cofferdam in the temporary offtake canal and to raise the dam beams in all 10 bottom sluiceways of the spillway dam, which was accomplished by 7 p.m. on September 21, when work on the gap was begun. Of the total discharge of the Don River during this period (250 cu m per sec.), 33 cu m passed through the bottom sluiceways in the spillway dam, and 217 cu m per sec. through the gap in the rock banquette. Flow velocities of the water in the gap reached at times 3.90 m per sec.

Rock was tipped according to schedule simultaneously through all the openings in the bridge in order to achieve a uniform rock fill throughout the length of the gap. At the same time, intensive hydraulic-filling of sand from the upstream side was begun by seven powerful suction dredgers which pumped their spoil from both sides of the river through a system of pipe lines (Fig. 32).

Excellent results were achieved on this responsible job thanks to good organization, careful briefing of every single participant, and to the fact that a trial test was made of all operations. The gap was closed with the rock raised to a height of 50 to 70 cm above water level, and the surface flow of water over the banquette was stopped within 4 hours after the first rock was tipped into the gap; dumping of rock continued another three hours to widen the profile and raise the crest to the required level. Table 10 gives the results of the filling of the gap.

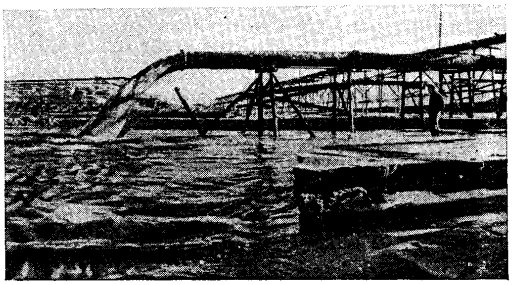

Fig. 32. Hydraulic filling of earth dam

*Table 10*

| Time in hours | Volume of rock dumped in cu m per hour | Accumulative total | Intensity of rock dumping in cu m per hour per linear metre in clear |
|---|---|---|---|
| 7-8 p.m. | 297 | 297 | 4.82 |
| 8-9 p.m. | 294 | 591 | 4.77 |
| 9-10 p.m. | 300 | 891 | 4.87 |
| 10-11 p.m. | 378 | 1,269 | 6.14 |
| 11-12 p.m. | 300 | 1,569 | 4.87 |
| 12-1 a.m. | — | 1,569 | — |
| 1-2 a.m. | 360 | 1,929 | 5.84 |
| 2-3 a.m. | 345 | 2,274 | 5.60 |
| 3-3:50a.m. | 288 | 2,562 | 5.62 |

*Note:* Tipping was stopped between 12 midnight and one o'clock in the morning in order to dismantle the foot bridge on the tailwater side and to tighten the span structure of the main bridge.

As may be seen from these figures, 330 cu m per hr. of tipped rock was average intensity, while a maximum was reached of 378 cu m per hr., which is equal to a 24-hour rate of 9,000 cu m. At the very moment the gap was closed, the total drop of the river in the gap was 43 cm; immediately after closing, it became 74 cm.

The results achieved as to the time required to close a river channel having a sand bed and a large discharge, and also as to rate of filling, are exceptional and may be regarded as a considerable achievement in hydraulic engineering.





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## CHAPTER SIX

## MECHANIZATION OF HEAVY WORK

*Earth Work*. The total volume of earth moved at the project amounted to 92 million cu m, and accounted for 25 per cent of the total cost of all construction and installation work.

The degree of mechanization of earth work at the construction site of the Tsimlyanskaya development in 1951 was 98 per cent. This testifies to a new high in the mechanization of earth work if compared with the 45 per cent level reached during the construction of the Moscow Canal and 84 per cent in the building of the Uglich and Shcherbakov hydroelectric stations. Table 11 gives (in millions of cu m) the volume of earth moved in the building of each structure according to type of work.

*Table 11*

| Structure | Total volume | Hydraulic fill | Excavators | Scrapers and bulldozers | Other machinery |
|---|---|---|---|---|---|
| Spillway dam, powerhouse, cofferdam, and canal | 14.5 | 7.65 | 3.50 | 2.78 | 0.57 |
| Earth dam | 45.9 | 29.43 | 5.38 | 9.87 | 1.22 |
| Shipping canal installations, canals and dikes | 13.8 | 2.25 | 5.92 | 5.07 | 0.55 |
| Other structures | 18.4 | 4.17 | 2.71 | 8.85 | 2.67 |



The hydraulic dredging of slit trenches in the river channel and the stripping of everburden in hydraulic-fill borrow pits are considered as belonging to individual structures.

A distinguishing feature of earth work mechanization at the Tsimlyanskaya project is the all-round use of such modern powerful machines as: electric suction dredgers of the 500-60 type, ESh-1 walking draglines, SE-3 electric shovels, scrapers, bulldozers and other earth-moving machinery. The new MAZ-205 and ZIS-585 tip lorries played an important role in haulage, thus helping the excavators to maintain a high level of efficiency.

The earth work accomplished is given in Table 12 in per cent according to type of machine.

*Table 12*

| Type of Machine | 1949 | 1950 | 1951 | 1952 | Total |
|---|---|---|---|---|---|
| Excavators | 18.0 | 25.1 | 14.6 | 25.1 | 19.1 |
| Scrapers | 17.8 | 24.6 | 14.9 | 7.7 | 14.7 |
| Bulldozers | 10.1 | 10.1 | 11.6 | 23.4 | 14.4 |
| Hydraulic machinery | 47.4 | 35.3 | 56.9 | 35.6 | 47.5 |
| Dredgers | 0.5 | 1.6 | — | — | 0.3 |
| Other types | 6.2 | 3.3 | 2.0 | 8.3 | 4.0 |
| *Total* | 100 | 100 | 100 | 100 | 100 |

The part played by hydraulic machinery was outstanding, if we consider that of the 92 million cu m of earth moved, it handled approximately 44 million cu m (about 48 per cent). A second prominent feature is the increasing rate at which the work was accomplished: a jump was made from about 4 million cu m in 1949 to approximately 49 million cu m in 1951. This work proceeded simultaneously with mastering of new equipment.

The different types of machinery used in the earth work were utilized as follows: suction dredgers were used at the



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beginning to excavate the pit for the powerhouse and spillway dam and to fill the cofferdam protecting the excavation; afterwards they were used in building the earth dam.

The following preparatory work was carried out prior to filling the earth dam: the removal of vegetation and plastic silt soils, the building of a trestle, the laying of pipe lines, the clearing of trees and stumps and the stripping of overburden at the borrow pits.

Hydraulic filling required a tremendous amount of preparatory work. Over 10 million cu m of earth, which is upwards of 30 per cent of the total volume of sand that was placed in the body of the dam, was removed in preparing the foundation of the dam and in stripping the overburden from the borrow pits.

One hundred and sixty-five km of trestle was erected. It was 5.5 m in height and made of wood. The total length of all the pipe lines laid during the construction period reached 301 km. Twenty-two tractor-type crane pipe-layers, three crawler cranes, three autocranes, twenty-one tractors and ten timber carriers were used in building the trestles and laying the pipe lines.

A 6-kV network of power lines from the central step-down substation was established to supply the hydraulic equipment with power. In addition, a 10,000-kVA substation was erected on the west bank especially for the hydraulic machines.

In order to remove the clarified slurries, a system of drainage ditches was built, designed to pass a discharge of water of 4 to 10 cu m per sec. The total discharge of drained water reached 20 cu m per sec. During the filling of the dam in the district of the Solyonaya River it was necessary to build a temporary reservoir with the water discharged through launders and pipes. Seven 0.5-cu m power shovels handled the digging of the drainage ditches.

The cost of the auxiliary construction work, including the building of trestles, the laying of pipe-lines, and the digging of drainage ditches, came to 2 rubles 25 kopeks per



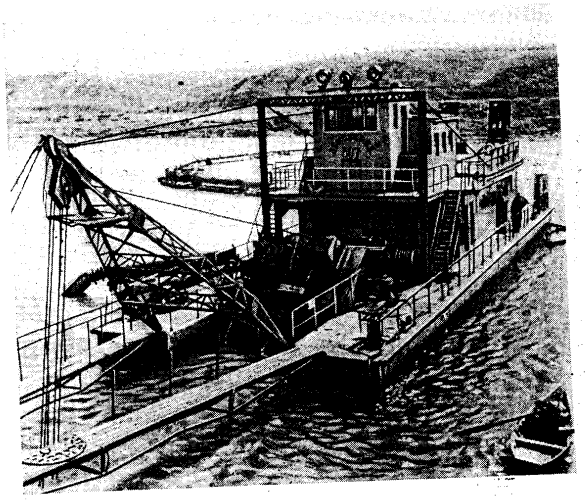

Fig. 33. General view of 500-60 suction dredger

cu m of the total volume of hydraulic-fill work accomplished.

A total of 29 electric suction dredgers participated in the building of the hydraulic-fill earth dam. Among the dredgers were 11 of type 500-60 (Fig. 33), 12 of type 300-40, and six of type 100-35. There were also 19 pumping stations, of which seven were of type 500-60 and 12 of type 300-40.

The organization of hydraulic filling of the dam from both sides consisted in creating a constant flow of spoil into the body of the dam, utilizing the maximum output of the dredgers. The filling was done in layers 400 to 800 m in length. The pipe-line ran on wooden trestles along the perimeter of the given layer and had outlet openings from 150 to 200 mm in diameter for placing the spoil in the layer



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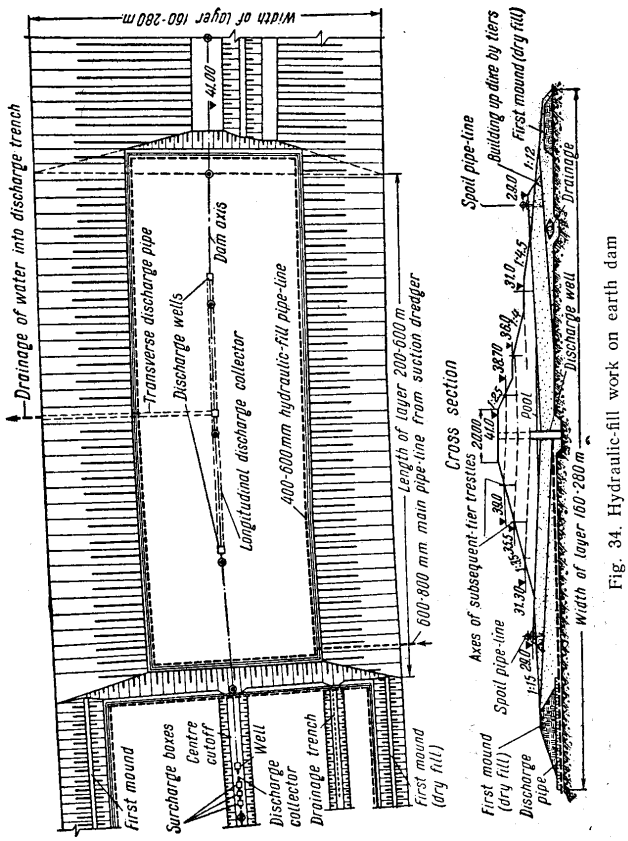


Fig. 34. Hydraulic-fill work on earth dam

(Fig. 34). In the immediate vicinity of the slopes of the embankment, bulldozers built up a mound 1 to 2 m in height, a so-called "first" mound which was built up further as the filling continued.

Wooden launders or board energy dissipators were set up opposite the outlet openings of the pipe-lines to dissipate the energy of the spoil flowing out of the pipes, and also to distribute it properly. The clear water from the fill layer was drained off through wells located in the central part of the pool, to steel pipes and thence into the open drainage ditches. After completion of the dam, these wells and pipes were filled with a cement mix and covered with sand.

Erection of trestles and shifting of pipe-lines to new filling levels was carried out in accordance with a work schedule that dovetailed with the filling schedule. This considerably speeded up transfer from one level to the next and in this way cut the idling time of the dredgers.

The suction dredgers actually reached an output higher than rated, and in 1951 the average monthly output was 224,000 cu m per 500-60 dredger, 102,000 cu m per 300-40 dredger (this included operation in the winter months), and 20,400 cu m per 100-35 dredger. During the summer months, the 300-40 dredgers gave an average (during six months in 1951) of 130,000 cu m per month. Output per machine (of those on duty) in 1951 was 1,230,000 cu m for the 500-60 dredgers, and 780,000 cu m for the 300-40 dredgers. The electric power required per cubic metre of hydraulic fill was 4.3 kWh for the 500-60 dredgers and 4.8 kWh for the 300-40 dredgers (this included electricity used for lighting and at the pumping station).

The bare cost of one cubic metre of fill placed in the body of the dam amounted to 5 rubles 43 kopeks for the 300-40 dredger and 4 rubles 85 kopeks for the 500-60 dredger (this data does not include expenses connected with trestle erection and pipe-laying).

The well-coordinated, efficient work of the hydraulic dredgers produced excellent results. In the course of 1951,



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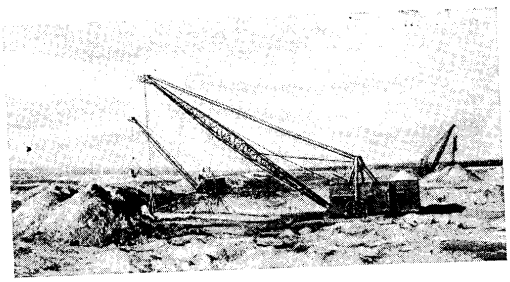

Fig. 36. ESH-1 draglines on earthwork

plished on the downstream shipping canal (the flood plain of the Don). The geological conditions were unfavourable because of much sandy loam and pure sand with a high water content. Therefore, in order to create the most productive conditions of work for the excavators, the following system was adopted: after stripping the dry overburden, an axial trench was cut 1 to 2 m below grade by small-size electric suction dredgers of the 100-30 type. The water table was thus kept on a level with the bottom of the canal, permitting dry excavation work to proceed on both sides.

The second big job handled by the ESh-1 draglines was the excavation of the drainage trench of the earth dam (a total of 1,800,000 cu m) to a depth of 9 to 10 m.

From October 1, 1950, to July 1, 1952, the ESh-1 draglines accomplished 5,100,000 cu m of earth work, with an annual output per machine of 424,000 cu m, or 104 per cent of the rated output. The best operator excavated 522,000 cu m in one year. The dragline machines performed 45,400 machine-hours of work, which makes an average of 7,300 machine-hours of work per excavator without medium maintenance or major overhauling of the machines.

Mention should be made of the rapid repair work and of a number of improvements that made for efficient utilization of this type of excavator, namely: tightening of the crown support gear, a device to prevent the rope from slipping off the head pulley, fastening of the main reduction gears, a change in the design of the fastenings of the brake and friction bands on the winches, etc.

The excavator operators received a good training by participating in assembling the machines, and they were able, within a short time, to reach rated output.

Many of the ESh-1 operators were listed among the best workers of the project.

Dragline operator G. V. Gorelov mastered his excavator to perfection and used high-speed methods of work:

a) filling the bucket at such a distance from the excavator as would enable cutting down the paths of the bucket, thus saving an average of four to five seconds per cycle;

b) raising the bucket as the boom is swung to the spoil bank, with allowance for the inertia of the bucket, which resulted in a saving of about four seconds;

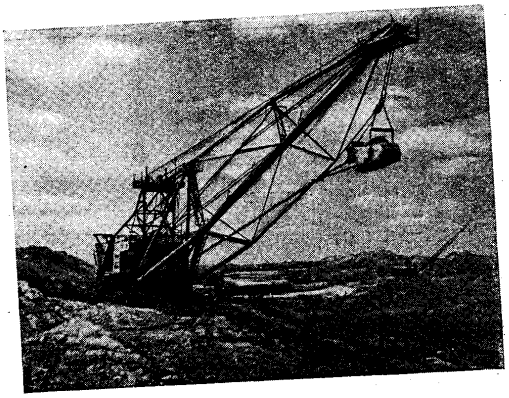

Fig. 37 ESH-14/65 dragline on watershed.





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c) also, lowering the bucket as the boom is swung back;
d) the dragline winch is turned on as soon as the bucket hits the bottom of the cut;
e) excavation of the cut without shoveling material. This saved 30 sec. and caused less wear on the lines.

All these methods of operation speeded up each cycle by 19 sec. as compared to the nominal rate, thus producing an additional 20 cycles per shift or 68 cu m of excavated material.

Monthly output figures of operators Gorelov and Vlasiuk are given in Table 13.

*Table 13*

| Name of operator | 3rd quarter of 1951 | | 4th quarter of 1951 | |
|---|---|---|---|---|
| | Volume in thousands of cu m | Per cent | Volume in thousands of cu m | Per cent |
| Gorelov . . . . . | 144.1 | 180 | 128.0 | 213 |
| Vlasiuk . . . . . | 180.4 | 210 | 90.4 | 150 |

Seven "Uralets" SE-3 power shovels were used to excavate the pits of the spillway dam, the powerhouse, and the canal locks. They were also used to excavate material at the borrow pits (Fig. 38) for the fills of the dam and dikes. Good use was made of the so-called high-speed all-work brigade system, each brigade consisting of the excavator crew, the drivers of the tip lorries attached to the excavator, the bulldozer drivers and road crews whose duty it was to keep in good repair the roads and spoil banks as well as the different-type rollers used when building up the embankments. Motor traffic was organized in one direction, along a circular route.



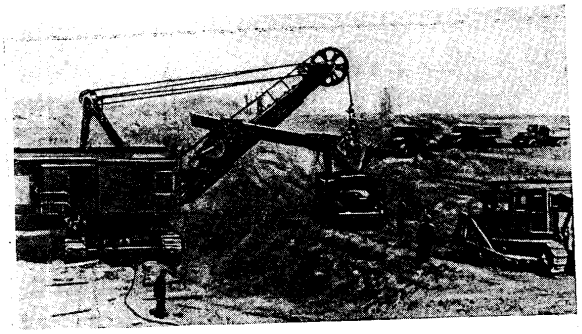

Fig. 38. SE-3 power shovel with 3 cu m dipper loading rock into MAZ-205 tip lorry

The SE-3 power shovels accomplished 152,200 cu m of earth work per year per cubic metre of dipper of this type of excavator, or 122 per cent of the nominal quota. Power shovel SE-3 No. 200 moved 1,356,000 cu m of earth during the period of construction without a single overhauling. The crew of this machine improved work methods and cut the time of each cycle from 34 to 23 seconds. Output per month reached 95,300 cu m, and up to 6,000 cu m per 24 hours.

Twenty-four 1-cu m excavators of the E-1003 and E-1004 type and fifteen 0.5-cu m power shovels were used mainly in concentrated groups to trim the excavation pits and for loading at the sand, gravel, and crushed-stone yards. The E-1003 power shovel, working in sandy soil, achieved a monthly output of 52,100 cu m and proved very manoeuvrable. In 1951, all 1-cu m excavators moved an average of 135,300 cu m per cubic metre of dipper, while the 0.5-cu m shovels did 138,800 cu m.

The work accomplished by different types of excavators during the period from 1949 to 1951 is shown in Fig. 39.



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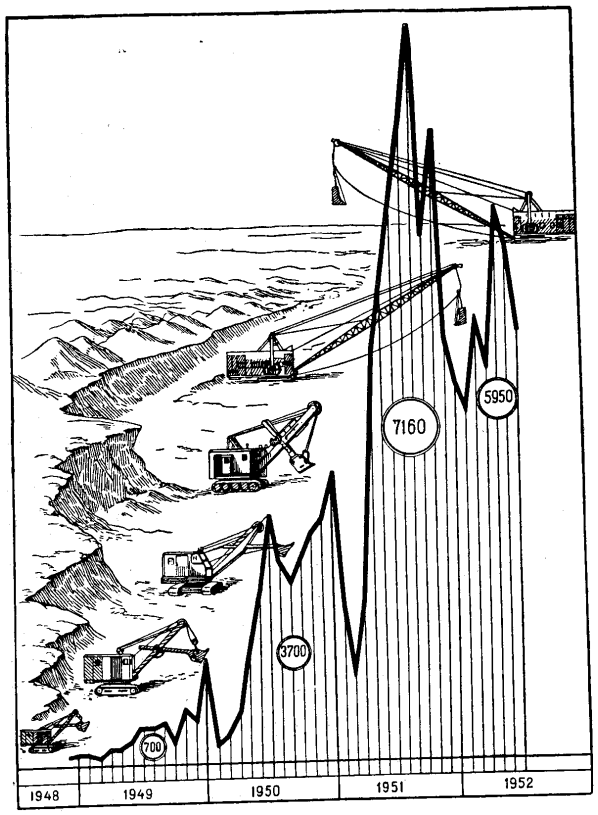


Fig. 39. Earth moved by excavators
(circled figures indicate volume of earth moved each year in thousands of cu m)

Good results were shown by the small-size excavators thanks to a well-timed system of preventative maintenance, the excellent operation of hydraulic control gear, and also to the proper care of the machine. The utilization coefficient of all types of excavators throughout the period of construction was kept within an average of 0.6-0.7 per year. It should be mentioned that after certain repairs following the completion of the project, nearly the whole fleet of excavators was shifted to new jobs.

Among the best operators working on the SE-3 power shovels, the highest results were obtained by Hero of Socialist Labour G. P. Simak, senior excavator operator of the crew of power shovel No. 200 that was engaged chiefly in sandy-soil work. Simak's method consisted in the following: he began the cut from the loading side of the lorry, thus lessening swinging time by reducing the angle; then, as he gradually moved farther away from the first cut, he shoveled the spoil closer to the road, which kept the path of the shovel clear, making movement easier.

In lowering the dipper into the cut, the stick is pushed down until the dipper teeth are 20 to 30 cm from the bottom of the cut; the dipper then takes up an even layer of ground. The fully loaded dipper is swung towards the point of unloading with the engine working at full speed; the engine is then turned off, with allowance made for movement due to inertia. As it swings, the bucket stick is pushed forward just far enough for the bucket to unload over the centre of the lorry body. A road sign is used to indicate the parking place of the vehicles. After tripping the dipper, the operator swings the boom and lowers it at the same time. The crew of power shovel No. 200 achieved excellent results due chiefly to strict observance of maintenance rules and to a big cut in the time spent on auxiliary jobs.

Senior excavator operator S. I. Silaev made a study of Simak's experience and used the following method in sandy loam soils: all operations (filling of the dipper, swinging, unloading, returning and lowering it into the cut) are done



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without a stop. Silaev ensures full dipper by working mainly at close quarters. The thickness of the bite depends on the height of the cut and the condition and character of the soil; the cut is kept wide enough for uninterrupted loading of the lorries. The excavator is moved during 30 to 40 seconds when the work stroke of the stick has been utilized 75 per cent. Silaev spent 31.4 seconds per cycle when working in 3rd and 4th class soil that was partially frozen (down to one metre).

Table 14 shows the results achieved by operators G. P. Simak and S. I. Silaev.

*Table 14*

| Name of operator | 3rd quarter of 1951 | | 4th quarter of 1951 | |
|---|---|---|---|---|
| | Volume excavated in thousands of cu m | Per cent of plan | Volume excavated in thousands of cu m | Per cent of plan |
| Simak . . . . . | 187.8 | 156.8 | 183.8 | 130.5 |
| Silaev . . . . . | 189.8 | 146.5 | 139.1 | 118.0 |

The lorry drivers attached to the SE-3 electric shovels played an important part in raising the efficiency of the excavator. One of the best drivers, P. A. Zubkov, succeeded in 1951 in making 245 per cent of the average annual quota. He had considerable experience in driving at high speed on 3rd and 4th class roads. Driving a MAZ-205 lorry, he achieved an average technical speed of 23.9 km per hr. with an average efficiency of 111.1 ton-km per hour. Zubkov achieved these results by skilfully utilizing the inertia of the machine, by cutting the time required to place the lorry for loading, by speedy dumping, and because of constant economy of fuel and lubricants. On the initiative of Zubkov, a joint competition of excavator crews and lorry drivers was organized. It produced good results and increased both speed and efficiency in the excavation work.



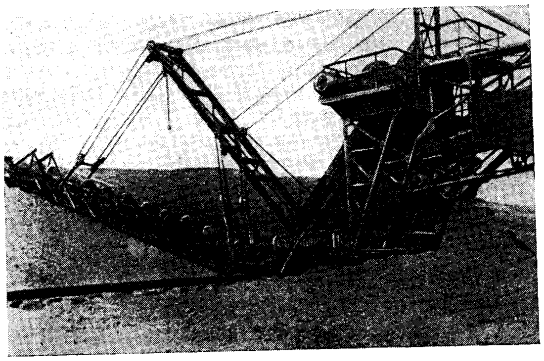

Fig. 40. EM-301 elevator dredger used for trimming canal and dike slopes

Elevator dredgers of the EM-301 (Fig. 40) and the EM-302 types were used to trim and plane the slopes of the canals and dikes.

A big role in the earth work was played not only by the excavators and electric suction dredgers, but also by D-213 and D-147 scrapers (Fig. 41), and D-157 bulldozers. Twenty-nine per cent of the total volume of earth moved at the project was handled by scrapers and bulldozers. They were used mostly in preparing the foundation of the earth dam. This consisted in stripping the overburden and in digging cutoffs up to three metres in depth, and also in moving earth for the dams and dikes, in stripping overburden at the borrow pits for the hydraulic machines, and in trimming work on the dam and shipping canals. In addition, the scrapers and bulldozers did a big job at the sand, gravel, and crushed-stone yards and in taking care of the spoil banks and approach lanes to the excavators.



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The nominal quotas for scrapers were fulfilled 90 per cent, while those for the bulldozers were considerably overfulfilled.

At the construction site there was a total of 245 scrapers and up to 112 bulldozers.

The best scraper operators used every moment of the workday and applied improved methods utilizing to advantage the peculiarities of the scraper—increasing the tractive power when cutting inclined layers (V. M. Poltavtsev), and speeding up filling of the scoop (N. A. Goncharov). They took excellent care of the machines and overfulfilled their quotas regularly, as may be seen from Table 15.

The best bulldozer operators made even higher showings, in varying conditions of work, as may be seen from the figures in Table 16.

*Building the Dam and Dikes.* Over three million cubic metres of earth was dumped into the dam dry and compacted to a bulk weight of dried ground of 1.6-1.7 tons per cubic metre. Typical profiles of rolled-fill and hydraulic-fill earth dams are given in Fig. 42. The earth fill was supplied by excavators from the nearest profile excavation and transported by tip lorries. Less often, the material was obtained by excavators from borrow pits; in the case of low embankments, the earth was moved by scrapers from nearby borrow pits.

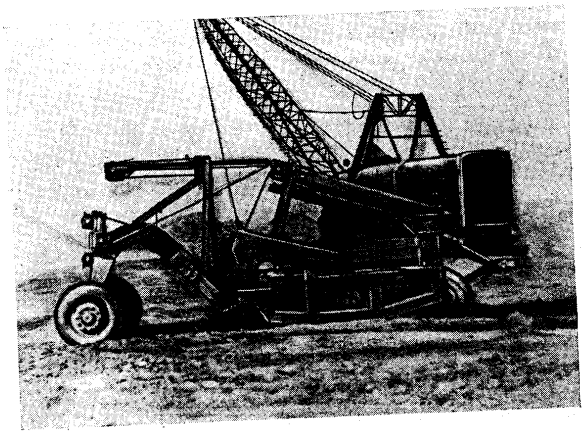

Fig. 41. D-147 scraper used in clearing the site for the dam



*Table 15*

| Name of scraper operator | Volume for one quarter-year in thousands of cu m | Per cent of quota |
|---|---|---|
| Poltavtsev | 36.9 | 180 |
| Goncharov | 32.0 | 160 |
| Kovalenko | 30.8 | 155 |

*Table 16*

| Name of bulldozer operator | Volume for one quarter-year in thousands of cu m | Per cent of quota |
|---|---|---|
| Shingarev | 42.7 | 197 |
| Krapivkin | 29.4 | 186 |

The earth dumped from motor vehicles or moved by scrapers was spread out by bulldozers and graders in layers of 25 to 30 cm and then compacted by ordinary sheepsfoot rollers. When compacting was done by 30-ton sheepsfoot rollers or 25-ton pneumatic-tyred rollers, the layer of earth was increased to 70 cm. The fill material was usually delivered with a natural humidity of 12 to 17 per cent. Fill work



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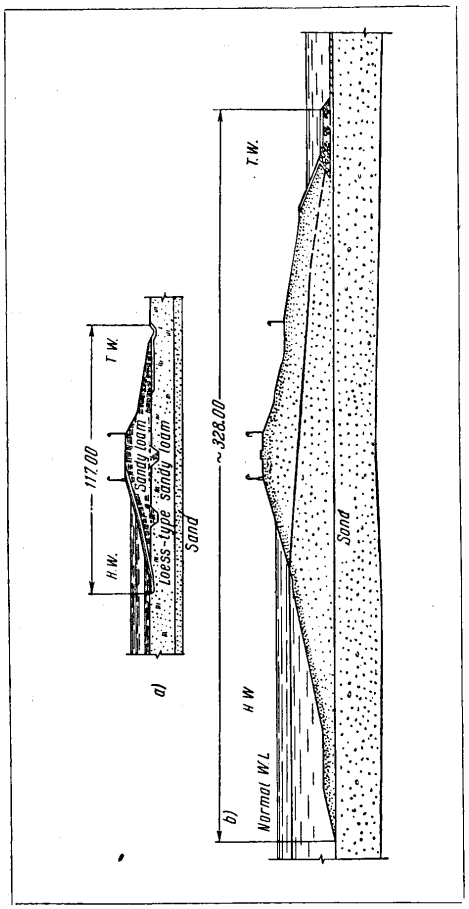


Fig. 42. Typical profiles of earth dams
a) dumped dry; b) hydraulically filled.

went on continuously both summer and winter, with stricter control during the winter time because the dumped soil froze and snow had to be cleared away. The fill work was handled by mechanized brigades that had at their disposal all the necessary machinery as well as specially assigned motor transport.

The experience gained shows that in order to carry out high-quality fill work for still larger earth structures, it is necessary to continue practical testing of powerful, new-type rollers, to study the conditions of maintaining optimal humidity in the cuts and the spots where the earth is placed, and to take other measures making for faster work of higher quality.

The economic indices of the work of different machines handling earth work may be seen in Table 17 from the figures given by K. F. Matskevich on excavators, A. N. Potapov on hydraulic machinery, and tentative data on scrapers. Although these figures are approximate, they show that the most economical methods of work are excavation by scrapers and excavators without transportation of the material.

Hydraulic methods of earth work occupy an intermediate position. With the introduction of new methods of work (the non-trestle method and others) and more powerful dredgers (the 1000-80 dredger), like those used at the Kuibyshev and the Stalingrad hydro developments, the economic indices of hydraulic-fill work improved.

Excavation work connected with motor haulage may be further improved by increasing the carrying capacity of the tip lorries.

The work methods of the drivers and operators were, as a rule, discussed at meetings and scientific-technical conferences, at which an active part was played by the professors and teachers of the technical institutes of Rostov Region.

It should be pointed out that excavators working in open pit coal mining show still higher output figures. In this



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*Table 17*

| Machine | Average cost in rubles per cu m | Consumption of electric power in kWh per cu m | | Output per shift in cu m | Category of soil |
|---|---|---|---|---|---|
| | | Summer | Winter | | |
| ESh-1 dragline | 3.53 | 1.6-2.2 | 1.3-2.5 | 90 | I-IV |
| SE-3 power shovel | 5.60 | 0.6-0.75 | 0.6-0.8 | 114 | I-IV |
| E-1003 and E-1004 excavators: | | | | | |
| dumped | 2.32 | 0.55-0.65 | 0.6-0.7 | 60 | I, II, III |
| transported | 7.28 | 0.35-0.45 | 0.45-0.50 | 60 | I-IV |
| E-504 excavator | — | 0.45-0.60 | 0.50-0.70 | 59 | I-IV |
| 500-60 suction dredger | 4.85 | 4.3 | — | 219 | Sand |
| 300-40 suction dredger | 5.43 | 4.8 | — | 97 | Sand |
| 6-cu m D-147 scraper | 2.50 | — | — | 100 | I, II |



Fig. 43. Four-layer filter around 800-mm dia reinforced concrete drainage pipe

work, use has been made of bank formers and rotor excavators.

As far as conditions of mechanization are concerned, *rock facings, filters and drainage systems* also belong to the class of heavy work, similar to earth work. The slopes of canals and dikes were protected by a rock pavement placed on a three-layer filter foundation. The filters under the facing of the toe apron, the down apron, and the slopes of the dam were also of the three-layer type.

After the hydraulic filling of the body of the dam, a drainage system was built on the downstream slope, with ESh-1 draglines used to cut the trench. Round, reinforced concrete pipes were then laid in the trench (Fig. 43) and were covered with a four-layer filter overlaid with an inverted filter. This work was done by bulldozers.

The plans called for filter layers 10 to 30 cm thick and rock protection 30 to 40 cm thick. The under layer of the filter was of large-grained sands with 50 per cent of the particles between 0.6 and 1.0 mm. The next layer contained



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small gravel or broken-up rock with 50 per cent of the particles 6 to 15 mm. The third layer consisted of crushed stone or gravel with particle-sizes ranging from 10 to 40 mm, and the fourth layer of 80-to 120-mm rock or cobble.

According to plan, the foundations and slopes for the filters were planed by bulldozers with a tolerance of $\pm 5$ cm. Filter materials at the yard were loaded into tip lorries by 0.5-cu m and 1-cu m power shovels. On horizontal sections the filters were dumped into place from lorries that drove up along special approach lanes. After this, bulldozers took over to spread the material out. Conveyors and cranes were used on the slopes. However, owing to frequent shifting and reloading operations, this type of mechanization was not a success. Steel trays were used widely on steep slopes and drag harrows on gradual slopes.

Rock-pavement work was hardly mechanized at all, especially the placing of the rock. The total volume of work accomplished on the filters, drainage systems and paving amounted to 2,500,000 cu m. The experience gained in this work shows that rock pavements are not well adapted to complete mechanization and should be replaced by other types of facing. The filter-laying machines tested on the Lenin Canal require further improvement.

*Steel Sheet-Pile Driving.* The steel sheet piling was driven below the foot of the structures and therefore no large-scale placing of concrete could be done in the main massive parts of the spillway dam and powerhouse structures prior to the pile driving. Likewise, no work could be done on the upstream apron of these structures or on the conjugate walls.

The steel sheet piling was of the ShK-0 type with a channel section. Most of the piling was driven to a depth of 14 to 20 m, and approximately 40 per cent to depths of less than 10 m.

The total volume of sheet piling driven at the project came to approximately 14,000 tons, of which 9,200 tons were driven at the spillway dam and powerhouse. Fig. 44

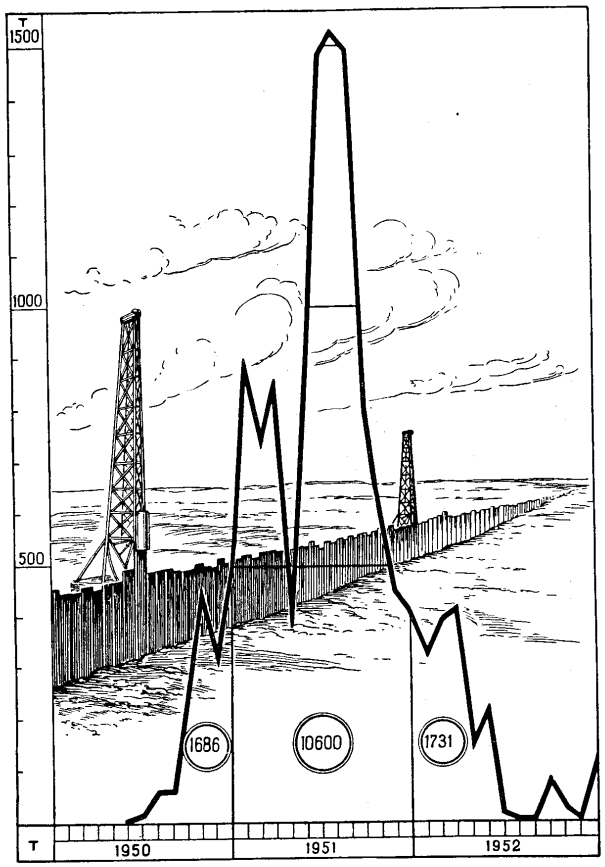


Fig. 44. Steel sheet pile driving diagram
(circled figures indicate the volume of work accomplished during each year, in tons)



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shows the progress of the work. At first, use was made of the electric vibrators proposed by Professor D. D. Barkan and employed in sheet pile driving in the cellular cofferdams during the construction of the Gorky hydroelectric station. A large-scale experimental driving of sheet piles was conducted over a period of several months and supervised by Professor Barkan himself. However, positive results were obtained only on certain sections and where the depth was less than 10 m. This was due apparently to the geological peculiarities such as the presence of individual layers of former river channel sandy loam in the sand. Likewise, no positive results were obtained in experiments with other types of vibrators proposed by Tatarnikov and Tsaplin.

At the same time, experimental driving of sheet piles was done with heavy 2- to 6-ton single-action steam hammers, allowance being made for considerable resistance in the locks of the pile planks. In these experiments, the best results were obtained in driving to depths up to 9 m, using a pile-driving unit with a single-action 2-ton steam hammer. Heavier single-action hammers did not produce good results, probably because the piling was not rigid enough.

At a trial driving made at the same time, good results were obtained in the use of a No. 7 double-action hammer with 245 blows per minute. Satisfactory results were also obtained with No. 9 and No. 10 double-action hammers.

Measures were taken to make use of portable crane pile drivers (chiefly with the No. 7 hammer) mounted on an E-1004 excavator, and also of six tower-type pile drivers with No. 9 and No. 10 hammers. Guides of the simplest type, consisting of two pieces of pile planks bolted together, were used in sheet pile driving.

Double-action hammers easily coped with metal sheet pile driving in the more favourable conditions of the port and locks. The general intensity of this work may be gauged from the fact that 10,600 tons of sheet piling was driven in 1951 alone. Despite this relatively high rate, sheet pile driving throughout 1951 was the main bottle-neck of all the construction jobs on the dam and powerhouse.



*Plain and Reinforced Concrete Work.* Plain and reinforced concrete work was fully mechanized. It included preparation of the concrete mix, manufacturing and placing of welded reinforcement, reinforced concrete slab panels, formworks; and transportation, pouring and treatment of the mix in the blocks. The concrete-pouring rate at the project exceeded the well-known records set during the building of the Dnieper Hydroelectric Power Station. The main part of the plain and reinforced concrete work accomplished in the building of the dam and powerhouse alone (per year and in thousands of cu m) is distributed as follows:

| 1950 | 1951 | 1952 |
|---|---|---|
| 61 | 977 | 175 |

A diagram showing the work done each year is given in Fig. 45.

One of the peculiarities of the structures of the Tsimlyanskaya hydro development as compared with large hydraulic structures built before is the greater volume of reinforcement used per cubic metre of concrete and the smaller size of the concrete blocks.

According to project calculations, the average weight of reinforcement in the ferro-concrete was approximately 47 kg per cu m. However, in certain structures it actually reached 75 kg per cu m. A comparison with other projects shows the following. The Tsimlyanskaya dam contains 47 kg of reinforcing steel per cu m of ferro-concrete as against 20 kg per cu m in the Ivankovskaya dam; and approximately 66 kg per cu m in the canal locks of the Tsimlyanskaya development as against 32 kg in the locks of the Moscow Canal.

The volume of the concrete blocks in the lower tiers of the main structures of the Tsimlyanskaya development was of the order of 1,200-800 cu m, rarely as much as 2,000 cu m,



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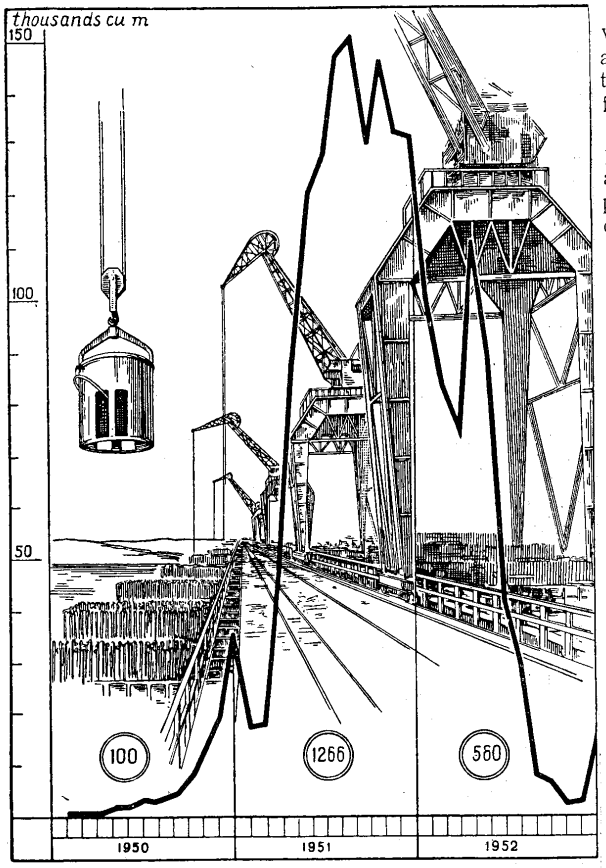


Fig. 45. Placing of concrete
(circled figures indicate the volume of concrete placed each year in thousands of cu m)

with an average, on the dam, of about 600 cu m, whereas in the other structures the average was 300 cu m. Of the total 822,000 sq. m of formwork, 106,000 sq. m was made for the slab panels and 30,000 sq. m for vacuumizing.

It was only through complete mechanization of the preparation, transportation and placing of the concrete mix and the use of industrial methods in manufacturing and placing the reinforcement and forms, that such high rates of concrete work could be achieved.

The reinforcement-welding plant had a capacity of 8 to 11 thousand tons per month and supplied the required amount of reinforcing steel, in line with the general rate of reinforced concrete work at the site. As a rule, there was no holdup in concrete pouring that could be traced to the work of the plant.

The reinforcement was mounted in the blocks by cranes which were also used for the formwork and the placing of concrete. The greater part of the reinforcement was placed in the spillway dam and the powerhouse by 10-ton portal cranes (Fig. 46).

In mounting the reinforcement of the piers at the dam and powerhouse, an attempt was made to reduce the hoisting cycle of the portal cranes and to create a reserve of mounted reinforcement. To do this, the reinforcing trusses were prepared for a number of piers simultaneously and for their full height, and were then put into place. The portal cranes thus made a saving of 1,350 hours of work. However, in the course of the work, it became clear that the manufacture of reinforcement trusses that correspond to the concrete blocks is more advisable.

The portal cranes did a good piece of work in mounting the reinforcement. Their efficiency, however, depended on the type of conjugation. On the average, one portal crane mounted up to 50 tons of reinforcement in a 24-hour workday.

The reinforcement of the toe apron, down apron, and retaining walls was mounted by crawler cranes. 3-ton



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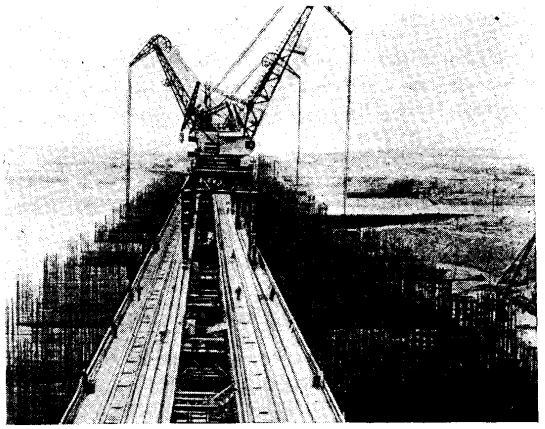

Fig. 46. Portal cranes mounting blocks of reinforcement

portal cranes and 8-ton cable cranes were used to place the reinforcement, forms and slab panels of the locks. In addition, T-72 cranes of 1.8-ton capacity were used in erecting the reinforcement of towers and other high, but light, structures.

The experience of reinforcement-welding work showed that its efficiency increases with the size of the members mounted, especially when it is possible to prepare the whole piece of reinforcement (comprising a block that may be filled in one lift) in the form of an all-welded structure (piers, walls, etc.). The method of large-block reinforcement not only raises efficiency in erection work, it also makes for a saving in metal because the number of erection rods is smaller. The use of automatic contact-joint welding and electric-arc welding in the manufacture of reinforcement



trusses in factories and during their assembly in the blocks of structures is of great importance in speeding up reinforcement-welding work.

As was mentioned above, nearly 100,000 tons of metal structures was manufactured and mounted during the building of the project. Of this number, 70,000 tons was accounted for in 1951 alone. This shows that mechanization of all the processes in the manufacture and erection of reinforcement ensured a rapid rate of work. It also cut the time required to prepare for the pouring of the concrete, which is one of the most important factors ensuring a rapid and constant rate in reinforced concrete work.

The experience of reinforcement-welding work at the Tsimlyanskaya development points to ways of further improvement by employing more powerful machines for contact-joint welding of the reinforcement, by using periodic sections, by making larger-size prefabricated reinforcement-welding frames, with rod reinforcement only in individual members where this cannot be avoided, and by a broader

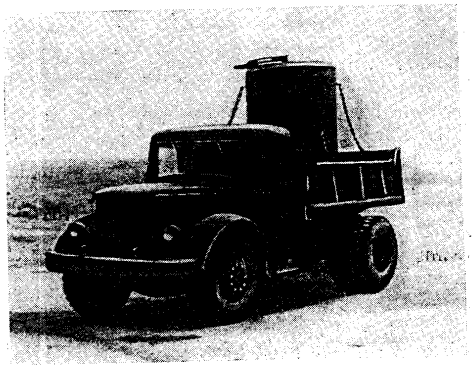

Fig. 47. MAZ-205 lorry carrying T-130 bucket



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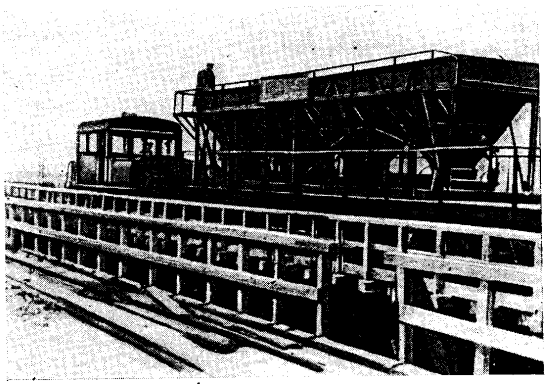

Fig. 48. Experimental steel hopper for transporting concrete mix

use of carrier sections of reinforcement, with the conditions and places for attaching the form frames and slab panels to the sections of reinforcement worked out in advance. All these methods will help to speed up construction work and make it cheaper.

The system of placing the concrete was based on delivery of the mix to the site in batches, for which purpose buckets, hoppers and ZIS-585 and MAZ-205 tip lorries were used. The different types of buckets used are described in Table 18.

MAZ-205 lorries (Fig. 47) were specially equipped for transporting concrete in T-130 buckets. T-103 buckets were used for transporting concrete by rail. Each 4-axle railway truck carried three or four buckets. Good results were obtained in the use of an experimental, 20-cu m steel hopper mounted on a railway truck (Fig. 48).

Such trucks loaded with 9 to 20 cu m of concrete mix were hauled by $M\frac{K}{2}15$ gasoline locomotives. The concrete



*Table 18*

| Type of bucket | Capacity, cu m | Type of gate | Tare weight, tons | Weight of bucket with concrete mix, tons |
|---|---|---|---|---|
| T-103 | 3.0 | Shutter | 1.70 | 8.9 |
| T-130 | 1.6 | Shutter | 1.00 | 4.4 |
| T-131 | 0.8 | Drop bottom | 0.45 | 2.4 |

was conveyed to the blocks of certain structures by belt conveyors, which received their mix from feeder hoppers filled by tip lorries. Table 19 gives the amount of concrete mix conveyed during the construction period by different types of transport.

*Table 19*

| Type of transportation | 1950 | 1951 | 1952 | Total | |
|---|---|---|---|---|---|
| | | | | Thousands of cu m | Per cent |
| Railway . . . . . | — | 515.2 | 187.0 | 702.2 | 36.5 |
| Motor vehicles . . | 104.8 | 751.0 | 373.7 | 1,229.5 | 63.5 |

The average 24-hour capacity of motor transportation was 2,850 cu m with a maximum of 6,200 cu m. The average efficiency of one vehicle over a hauling distance of two kilometres was 21.2 cu m of concrete mix per 24 hours during the first 10 months of 1951, and varied but slightly as to type of motor vehicle. Waiting time of motor vehicles during unloading at the blocks came to an average of 4 per cent in 1951, whereas that during loading at the concrete



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plants, with allowance for bucket washing twice per shift, amounted to 9 per cent of the work time.

The gasoline locomotives delivered an average of 1,694 cu m per 24-hour workday, and a maximum of 3,842 cu m. One locomotive delivered an average of 54 cu m of concrete over a 4-km route in one shift with 5 per cent waiting time for loading at the plant, and 18.3 per cent of the total work time spent in unloading. There were up to 20 locomotives on duty, with an average of 17 working. Up to 40 per cent of them were engaged in delivering reinforcement and forms.

The best drivers, among them Golubov, a member of the Young Communist League, made an average of 14 to 16 trips per shift as against the quota of 8. The traffic on the circular railway often exceeded 20 locomotives per hour. Mechanization of concrete pouring in the blocks of the structures was specialized according to conditions of placing. On broad areas (the toe apron, down apron, upstream apron, and slope facing of the dams and dikes) concreting was done mainly by 15-ton crawler cranes. These cranes were re-equipped excavators of the Voronezh and Stalingrad plants with booms up to 23 m in length. This type of crane delivered 1.6-cu m buckets of concrete, making a total of 7,400 cu m per month and up to 600 cu m every 24 hours. Between concrete runs, the crane mounted form frames and reinforcement.

Table 20 gives data concerning the utilization of crawler cranes on concrete work during the first 7 months of 1951.

Crawler cranes placed 31 per cent of the total amount of concrete deposited at the project.

At first, the plants called for pouring of concrete into the blocks of the toe apron and down apron with the aid of 10-ton gantry cranes. Good results might have been obtained by placing the concrete in belts one block in width, proceeding continuously along the whole length of the down apron. In practice, however, such a consecutiveness could not be maintained because of the conditions of excavation and drainage. As a result, the manoeuvrability of the gantry cranes was lost, and after several blocks had been poured these cranes were dismantled and used at the reinforcement-welding works (Fig. 49).



*Table 20*

| Month 1951 | Number of cranes | Number of work hours | Amount of work accomplished by the crane | | | |
|---|---|---|---|---|---|---|
| | | | Concrete placed, thousands of cu m | Reinforcement mounted, thousands of tons | Forms mounted, cu m | Various loads moved, thousands of tons |
| April | 13 | 3,516 | 39.5 | 0.75 | 188 | 6.1 |
| May | 13 | 3,377 | 51.7 | 1.87 | 476 | 6.1 |
| June | 14 | 3,824 | 59.6 | 2.41 | 237 | 10.8 |
| July | 15 | 5,022 | 53.8 | 3.35 | 1,520 | 22.8 |
| August | 15 | 5,074 | 53.1 | 5.43 | 1,660 | 28.4 |
| September | 15 | 6,570 | 32.2 | 2.39 | 1,874 | 63.8 |
| October | 10 | 3,706 | 14.9 | 2.00 | 790 | 34.9 |

Vibrating spouts were used for pouring the concrete from the concrete-delivery trestle into the lower tiers of the blocks of the spillway dam and powerhouse. The spouts proved very efficient and easy to install, which made for manoeuvrability along the whole line of the work that extended over some 600 linear metres.

The plans provided for the placing of concrete in the lower tiers of the blocks of the spillway dam with 10-ton portal cranes and 3-cu m buckets. During the concreting of the first blocks, serious difficulties were met due to the great height from which the buckets had to be let down, the swinging of the buckets and the difficulty of lowering them into the openings of the reinforcement frames, and also because of the big cycles, all of which resulted in reduced efficiency. The trial tests with vibrating spouts conducted at this time



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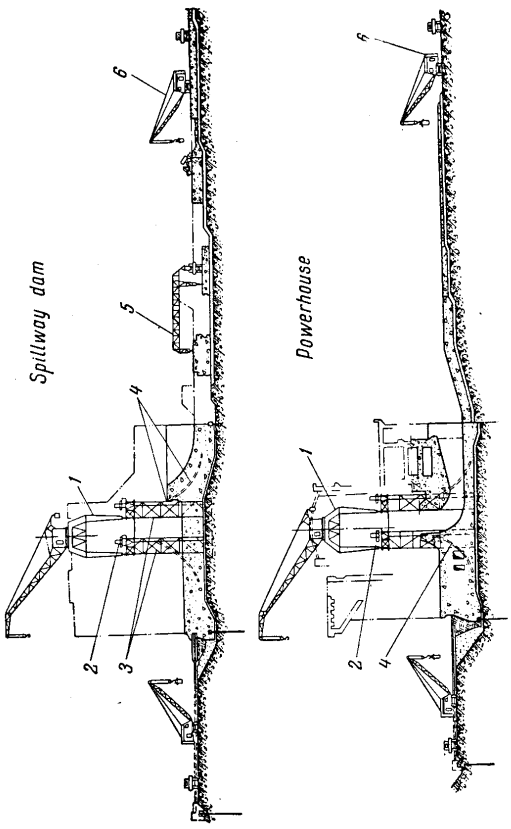


Fig. 49. General plan of concrete work, including types of machines used
*1*—10-ton portal crane with 30-metre boom; *2*—buckets of concrete delivered on railway trucks; *3*—steel concrete-delivery trestle; *4*—vibration spouts; *5*—5-ton gantry crane with 17-metre span; *6*—15-ton crawler crane with 13-metre boom.

produced good results, and in the lower tiers of the blocks the concrete was poured through these spouts (Fig. 50).

The S-267 vibrating spouts of the Rostokino Building Machine Works is a steel pipe with an inside diameter of 250 mm, made up of 1,000, 1,250 and 1,500-mm sections with ball joints and a hopper head 1.1 m in diameter. From 2 to 4 I-7 vibrators were attached to the sections along the length of the pipe and one vibrator to the hopper head.

The ball joints of the vibrating spout sections had hinges in several different planes, thus permitting the pipe to be bent in any direction. An emergency 12-mm dia cable ran the length of the pipe through special ears in the sections, in case these hinges broke.

The hopper heads of the vibrating spouts were attached to the upper structure of the steel trestle and were placed in such a way as to permit the simultaneous discharge of several buckets of concrete mix from the railway trucks on the trestle.

In the case of 1,000-cu m blocks, the concrete mix could be poured through 6 to 8 vibrating spouts with an average of 4 spouts working at one time.

With the capacity of one vibrating spout 25 cu m per hour, the pouring of one such block took less than 24 hours.

The number of vibrating spouts operating simultaneously from the trestle reached 60, thus making it possible to place concrete in several blocks at one time.

According to the figures of engineer E. F. Freighofer, a vibrating spout saves more than four rubles per cubic metre of concrete as compared with the cost of placing concrete with 10-ton portal cranes and 3-cu m buckets.

The use of vibrating spouts also made it possible to transfer the 10-ton portal cranes to the mounting of forms and reinforcement, thus speeding up preparatory work for concrete pouring.

In the construction of the spillway dam and powerhouse, the concrete mix was delivered by 10-ton portal cranes to blocks located above the trestle. Eight portal cranes were



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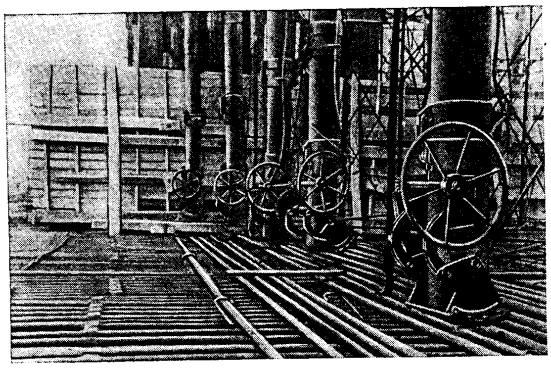

Fig. 50. Vibration spouts

at work along the 700 m of the trestle. They were also used to mount reinforcement and forms. The cranes had the following specifications: hoisting capacity at full length of boom—10 tons; length of boom—30 m; speed of horizontal movement—31.4 m per minute; hoisting speed—36.4 m per minute; lowering speed—30.1 m per minute; installed power of electric motors—176 kW; weight of crane—149 tons. Figures characterizing crane efficiency during the regular operation period are given in Table 21.

A total of 210,900 cu m of concrete was placed by the 10-ton portal cranes (Fig. 51).

The best 10-ton portal crane operators, such as I. E. Kochailo, A. F. Nazarov, and others, produced outstanding results and introduced the following rationalization proposals:

a) an additional window was cut in the front wall of the crane cab, thus improving the view from the operator's seat. This produced a 5 per cent saving in time;



*Table 21*

| Month | Number of cranes in operation | Number of work hours | Volume of concrete placed, cu m | | Amount of reinforcement placed, tons | Amount of forms placed, sq. m | Quantity of loads moved, tons |
|---|---|---|---|---|---|---|---|
| | | | Per month | One crane per 24 hours | | | |
| 1951 | | | | | | | |
| August | 6 | 2,969 | 4,859 | 27 | 7,179 | 484 | 10,465 |
| September | 7 | 3,023 | 9,207 | 39 | 7,424 | 1,602 | 25,250 |
| October | 8 | 3,682 | 21,863 | 90 | 3,152 | 2,256 | 23,733 |
| November | 8 | 2,298 | 27,243 | 155 | 2,775 | 2,226 | 22,760 |
| December | 8 | 2,584 | 35,980 | 240 | 2,007 | 1,634 | 15,113 |
| 1952 | | | | | | | |
| March | 8 | 3,720 | 27,330 | 117 | 5,411 | 1,578 | 35,794 |
| April | 8 | 4,576 | 25,219 | 106 | 170 | 8 | 43,434 |

b) an electric de-braking device was used that ensured smoother and more accurate placing of loads, and raised the efficiency of the crane about 8 per cent;

c) the cable swivel was made fast, thus preventing the cable from twisting.

Before beginning a job, the crane was first placed so as to work without changing the boom length if possible and to reduce the angle of swing to a minimum. In hoisting buckets of concrete, the operation of raising the bucket handle took place simultaneously with swinging the boom, thus making it possible to pick up the bucket, with the cable in a vertical position. This eliminated any swinging of the bucket.

In other operations, hoisting and swinging were also combined whenever possible. Observance of the rules of placing the crane and proper reckoning of the order and method of hoisting and delivering the loads (in coordina-



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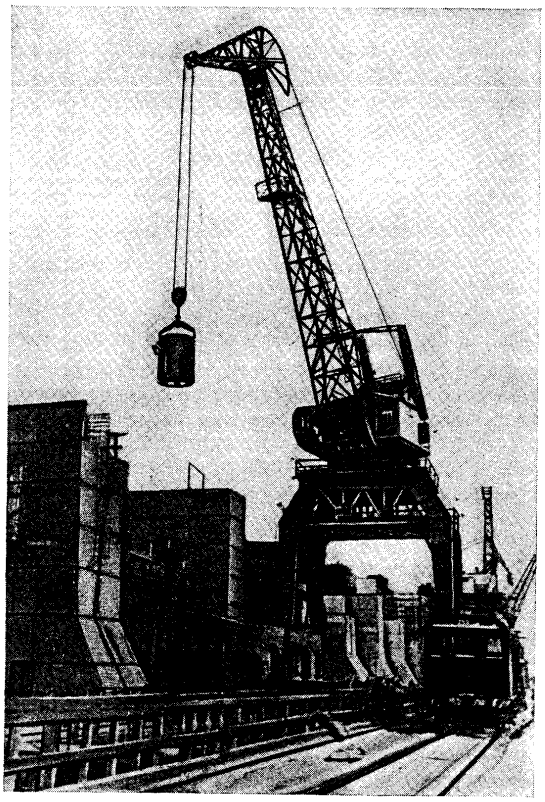

Fig. 51. 10-ton portal crane transporting 3-cu m bucket of concrete

tion with the erection workers and riggers) result in smooth work and efficiency, as may be seen from the figures of Table 22 (for different conditions of work).

*Table 22*

| Name of crane operator | First quarter of 1951 | | Fourth quarter of 1951 | |
|---|---|---|---|---|
| | Work done in machine-hours | Per cent of quota | Work done in machine-hours | Per cent of quota |
| Kochailo | 608 | 174.3 | 240 | 160.0 |
| Nazarov | 328 | 162.6 | 512 | 159.4 |

The use mainly of these three methods of depositing concrete in the largest structures of the project (the spillway dam and powerhouse) made for speedy pouring of concrete along the whole line of the job and for closely coordinated operations with motor and railway transportation facilities, thus ensuring an intensive and continuous placing of concrete.

The rate at which the concrete was placed in the structures of the spillway dam and powerhouse reached 120,000 cu m per month.

In the concrete work on the shipping canal installations the greater part (about 80 per cent) of the total volume of 228,000 cu m of concrete was placed by 600- and 800-mm wide belt conveyors. The concrete mix was delivered by tip lorries from hoppers equipped with arc gates. The hoppers were situated on the slopes of the excavation. In addition to conveyors, use was made of crawler cranes (7.1 per cent); a small part (4.4 per cent) of the mix was delivered by 3-ton portal cranes, which were used mainly in mounting reinforcement, slab panels and forms.

The concrete was deposited, as a rule, from bottom up along the whole length of the slope in order to make use



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of the ready, gradually sloping part at the bottom as a road for transporting the mix when placing concrete in the upper sections. The concrete mix was delivered by cranes and by vibrating chutes, using ordinary 1.6-cu m buckets and special buckets (Fig. 52) filled directly from tip lorries.

The concrete was placed in the slope facing of the earth dam chiefly by crawler cranes and vibrating chutes; it was also dumped directly from tip lorries.

Table 23 gives the volume of concrete mix placed in the various structures by year and according to the methods of delivery to the blocks.

The concrete mix in the blocks was treated chiefly with I-50 and I-21 depth vibrators and surface vibrators of the I-7 type. The form frames for the structures of the project were as follows: wood-panel type, vacuum formwork, and slab panels.

The total area of panel formwork manufactured at the carpenter shops was 128,000 sq. m, whereas the total area

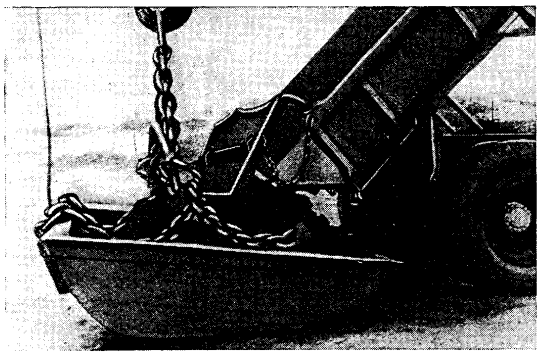

Fig. 52. Special bucket, filled from tip lorries, for delivery of concrete mix to point of deposit



*Table 23*

| Method of delivery of concrete mix to blocks | 1950 | | 1951 | | 1952 | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Volume, thousands of cu m | Per cent | Volume, thousands of cu m | Per cent | Volume, thousands of cu m | Per cent | Volume, thousands of cu m | Per cent |
| Crawler cranes | 39.3 | 37.5 | 409.5 | 32.4 | 140.2 | 25.0 | 589.0 | 30.5 |
| 10-ton portal cranes | — | — | 106.9 | 8.4 | 104.0 | 18.0 | 210.9 | 10.9 |
| Vibrating spouts | — | — | 404.8 | 31.9 | 19.7 | 3.5 | 424.5 | 21.9 |
| Tip lorries | 39.9 | 38.1 | 185.9 | 14.7 | 180.1 | 32.1 | 405.9 | 20.9 |
| Conveyors | 9.3 | 8.9 | 138.2 | 10.9 | 48.1 | 8.6 | 195.6 | 10.1 |
| Vibrating chutes | — | — | 6.1 | 0.5 | 55.4 | 2.9 | 61.5 | 3.2 |
| Concrete pumps | 1.2 | 1.1 | 2.8 | 0.2 | 0.8 | 0.2 | 4.8 | 0.5 |
| Other methods | 15.1 | 14.4 | 12.0 | 1.0 | 12.4 | 2.7 | 39.5 | 2.0 |
| *Total* | 104.8 | 100 | 1,266.2 | 100 | 560.7 | 100 | 1,931.7 | 100 |

of wooden forms, taking the structures of the project as a whole, amounted to 685,000 sq. m. Reinforced concrete slab panels covered 106,500 sq. m of surface on the structures, including 70,300 sq. m on the spillway dam and powerhouse, and 36,200 sq. m on the shipping canal installations. The reinforced concrete slab panels not only replaced the forms, but also offered a high-quality concrete for the structure surfaces that come in contact with the water and atmosphere. The surface of the concrete in the toe apron and spillway sections (Fig. 53) of the structures was treated by vacuumization in order to improve its durability and resistance to abrasion. The horizontal surfaces were vacuumized by portable vacuum panels that were made of waterproof plywood and were a part of the S-253 vacuum outfit that is capable of treating 11.5 cu m per minute. The area of concrete vacuumized at one time by a single outfit did not exceed



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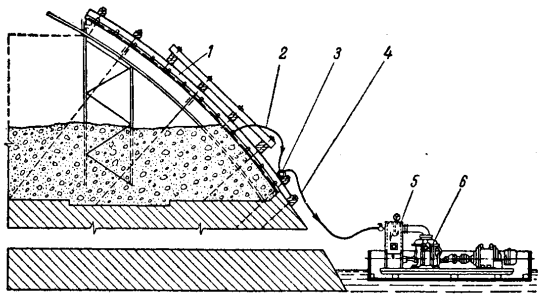


Fig. 53. Vacuumization of dam spillway face

*1*—vacuum-panel truss; *2*—suction hose; *3*—collector; *4*—vacuum-pump hose; *5*—header; *6*—vacuum pump.

12 sq. m. This method was used to treat the horizontal surfaces of the toe apron of the dam over an area of 84,500 sq. m. The curvilinear surfaces of the spillway dam in its lower part and at the head, where the slope of the surfaces did not exceed 20°, were vacuumized by curved vacuum panels (1.8×0.75 m). These panels were placed on the smoothed surface of the concrete. The sloping and vertical curvilinear surfaces of the spillway section of the dam and the baffles on the toe apron were vacuumized by using large-size panel forms (Fig. 54). One panel covered an area of up to 20.5 sq. m with a total weight of about 2.5 tons. From 4 to 8 panels were placed on each block of the dam. In the vacuumization of large blocks, use was made of RMK-4 vacuum pumps with a capacity of 27 cu m per minute each. In all, 30,500 sq. m of curvilinear and vertical surfaces of the dam were vacuumized. A total of 5,500 sq. m of large-size panel vacuum forms were built. Thus, the forms were used an average of 6 times.

In cold weather, extensive use was made of the thermos method of placing concrete with panel forms kept warm by



a double layer of sheathing filled with sawdust. Slab panels were kept warm by blankets of sackcloth with slag-batting or felt on the outside. During the actual pouring, use was made of tarpaulin covering and steam heating with steam air heaters or simple tubular registers. The steam was supplied from old locomotives not in use. As a rule, the concrete mix was produced at the plants with a temperature of +15°, +20° Centigrade. During transportation in the winter time, the buckets were covered, and the mix was heated by the exhaust of the tip lorries. In addition, calcium chloride was added to the mix used in slope-facing slabs and in the small blocks.

Mechanization of all the processes in plain and reinforced concrete work plus the application of the above-mentioned methods (slab panels, reinforcement trusses, vacuumization, etc.) enabled the builders to achieve a rapid and regular rate of work. The basic condition for this is rapid prepa-

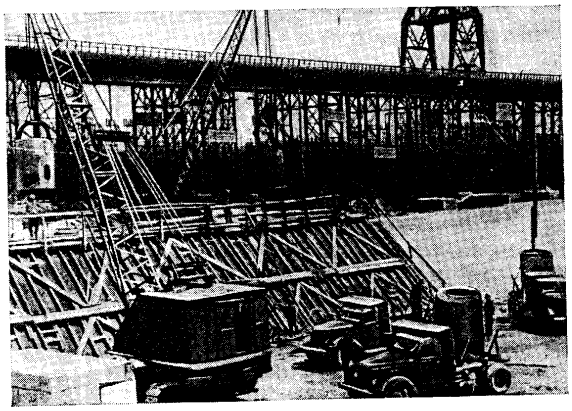

Fig. 54. General view of vacuum panels



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ratory work, for which purpose it is necessary (aside from the above measures) to mechanize the cleaning of blocks, especially in winter; to improve the efficiency of the vibrators and vibrator units; to make wider use of concrete pumps and larger-diameter vibrating spouts; to make wider use of machinery adaptable to the streamflow and continuous-work principles (railway transportation on circular routes, conveyors, etc.). It is also important to increase the volume of erection work by introducing pre-assembled structures and sections that enable speedy building of blocks for the pouring of concrete.

## CHAPTER SEVEN

## ERECTION AND INSTALLATION WORK*

The following volume of work connected with the erection of steel structures and the installation of technological equipment was accomplished at the Tsimlyanskaya development: 14,300 tons of steel structures, 2,930 tons of hoisting machinery, 3,600 tons of power plant equipment and 25,000,000 rubles worth of electrical equipment.

Installation of equipment was begun as soon as the concrete was ready. The installation of all the principal technological equipment was completed in the course of 9 months, from September 1951 to May 1952.

The completion, within a short period of time, of the erection and installation work was due to a broad system of mechanization of all heavy work and to the introduction of a new method of installing hydraulic equipment. The rate of this work was limited, at first, by the state of completion of the construction work and, towards the end, by the spring high water of 1952.

The method of installing hydraulic equipment at Tsimlyanskaya consisted in the preliminary assembly (at separate assembly bases) of whole hydro sets, steel structures, machinery or individual large sections, and their delivery to the required spot in assembled form.

All assembly jobs at the construction site were divided up between two assembly bases. The different jobs were assigned to one or the other of the bases according to the

* Compiled by Engineer K. S. Ivanov, head of erection and installation work at the project



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technological aspects of the job, and not to its territorial location. All the equipment of the power station was concentrated at Base No. 1. Base No. 2 handled the equipment of the spillway dam, the locks and the irrigation headwork.

Base No. 1 was situated at a distance of 500 m from the powerhouse and covered an area of 4.5 hectares. The base had five railway sidings with a total length of 1,750 m.

Five warehouses for equipment were built on the territory of Base No. 1, one warehouse with a system of heating for the storage of special equipment, and four cold warehouses. The latter covered an area of 1,200 sq. m. The first step was to divide up the entire open area of the base among the different sections of the project. This made it possible for freight arriving by rail to be unloaded at specified points. All warehouses, right up to the last shelf within them, were organized in the same manner. Each incoming item had its definite place in accordance with a previously worked out plan. Special attention was paid to conservation and periodic inspection of the equipment. Loading, unloading, and erection-installation work at the base was handled by two 45-ton and two 25-ton locomotive cranes, a 15-ton gantry crane, and a 15-ton crawler crane. Base No. 1 was connected with the powerhouse by a special railway line which made it possible to deliver freight from the base directly to the powerhouse by-passing the general service railway lines.

The equipment of all the other structures was concentrated at Base No. 2 which covered an area of 5 hectares, and was situated between the spillway dam and the locks at approximately an equal distance from each. In the immediate vicinity of the base, there was a railway line connecting the locks and the spillway dam; this also made it possible to deliver freight directly to the construction jobs without using the general railway lines of the project, which would have limited the over-all dimensions of the goods. Since the base was close to this special line, it was possible to deliver freight of any size.



Base No. 2 was equipped with two 25-ton rigid-leg jib cranes, a 25-ton locomotive crane, and a 15-ton crawler crane. Both bases had machine shops, forge shops, warehouses for assembly materials, and small-size garages.

The travelling cranes of the powerhouse were erected by a new method and far in advance of the preparedness of the crane rails. To do this, special mobile scaffolding was erected from the equipment at hand on an open site about 200 m from the end of the machine building. The scaffolding had eight two-wheel trucks and moved along a four-track railway line. The height of the scaffolding was such that the trucks of the crane erected on it were 20 mm above the head of the crane rails of the machine hall. Some of the sections of the travelling crane (the bridge, carriage, and some others) were assembled under the V-posts (hoisting capacity—60 tons) set up previously at this point for the erection of the portal building cranes. During the erection

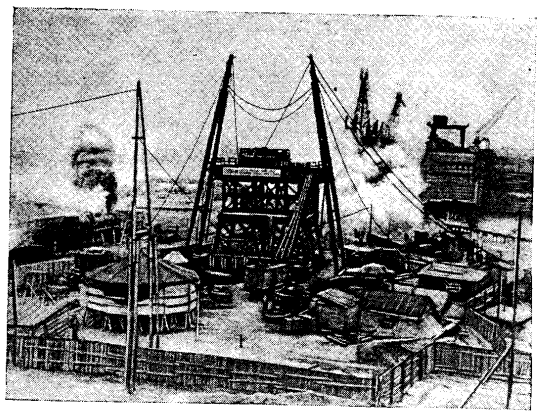

Fig. 55. V-posts used in erecting travelling crane



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the mobile scaffolding was stationed at some distance from the V-posts. As soon as each unit was ready, it was raised to the required height with the aid of the above-mentioned hoisting posts; the scaffolding was then rolled under the raised part, and the part was lowered onto it (Fig. 55). In this way, crane No. 1 was completely erected; this included installation of the cable lines and all its electrical equipment and a trial test of the carriage travel and hoisting mechanisms. At the same time, several units of crane No. 2 were assembled and were ready to be hoisted and placed near the V-posts.

As soon as the reinforced concrete girders under the crane rails were strong enough, the mobile scaffolding was drawn into the machine hall of the powerhouse with the aid of hand winches, and the assembled travelling crane was transferred from the scaffolding to the machine hall crane rails. It took 8 hours to run the scaffolding from the crane assembly grounds into the machine hall and to transfer the crane to the rails. Ten hours later the crane was ready to begin assembling of the first hydro unit. While the mobile scaffolding was being transferred, V-posts were used to hoist the bridge of crane No. 2, which was assembled in 5 days. Thus, six days after the crane rails in the machine hall were ready, both cranes with a hoisting capacity of 150 tons were already assembling the hydro units. This new method of assembling travelling cranes made it possible to put them into operation two and a half months earlier than usual.

The hydro units consist of 635-ton adjustable-blade turbines and 520-ton vertical generators. These units were of a new design, produced for the first time by the Elektrosila and LMZ plants. They differ from all earlier types in that the thrust bearing is not on the lower spider (as is usually the case), but is fixed to the cover of the turbine. The turbine stator does not consist of separate columns, as in earlier hydroelectric stations; it consists of 4 parts, each weighing 30 tons. A 45-ton locomotive crane on the con-



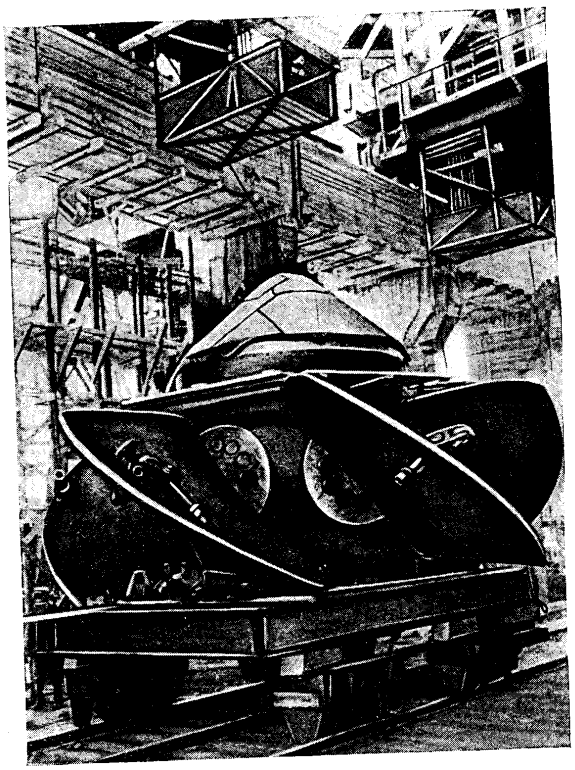

Fig. 56. Runner of adjustable-blade turbine on way to machine hall



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crete-delivery trestle directly under the turbine crater was used to lower the parts of the stator into the crater. Three parts of a stator could be lowered into the crater during one eight-hour shift.

At the Tsimlyanskaya station, the 153-ton turbine runners and the generator rotors were assembled outside the machine hall without the use of travelling cranes. The turbine runner and generator rotor were assembled on the same grounds as the travelling cranes. Assembling the turbine runner gave the most trouble. According to conventional practice the hubs of the runners of adjustable-blade turbines have to be canted in the course of their assembly, because the parts of the runner servomotor must be put into the hub in accordance with their size and order of assembly through a port in its lower part. After the parts have been placed in the hub, it must be turned back into its working position, and then the blades and other parts of the runner are put into place.

At the Tsimlyanskaya project a method of assembling the runner was worked out which did not require canting of the runner hub, thus making it possible to assemble the runner with an ordinary 45-ton locomotive crane. To do this, a special platform was built capable of holding 160 tons. It had four two-axle trucks and moved on rails. This platform was used as a stand for assembling the runner and also as a means of transporting it into the machine hall (Fig. 56). The parts of the runner hub which were to be put through the lower openings of the hub were assembled in a special pit. When they were assembled, the hub of the runner was rolled onto the pit. A rope was let down through the hub, and the assembled parts were hoisted by the locomotive crane from the pit into the hub of the runner where they were secured in their proper positions. To facilitate the assembly work, special tools and a large number of special balancing devices were manufactured. This method made it possible to assemble the runner whether the travelling cranes of the machine hall were ready or not.



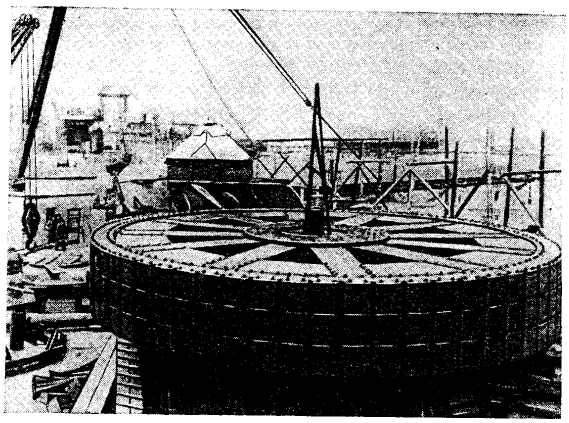

Fig. 57. Generator rotor being assembled on special stand

As soon as the travelling cranes were ready, the runner was put through the end of the machine hall into the installation yard and immediately lowered into the turbine crater. In this way, the 25 to 30 days usually spent in assembling the runner were completely eliminated from the hydro-unit installation schedule. The other parts of the turbine (thrust bearing of the machine, forced lubrication, upper spider, and others) were assembled and aligned on the grounds outside the machine hall.

The 175-ton generator rotor (without the poles attached) was likewise assembled on the same grounds. For this purpose also, a special platform was built that served at the same time as an assembly stand. The generator rotor (Fig. 57) was delivered to the installation yard immediately after the turbine runner.

The gates and dam beams of the Tsimlyanskaya power station (together with the trash racks they weighed a to-



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tal of 1,200 tons) were completely assembled at the assembly base, where the packings and the moving parts of the gates were installed. At earlier hydro projects, the supporting and moving parts of the gates were delivered for installation, already run in with the gates at the factory. At Tsimlyanskaya, these parts were run in during installation. Experience shows that in future the moving parts should be run in only during installation.

The different parts of the gates, dam beams, and racks, assembled at the base, were delivered to the powerhouse assembly yard, and from there they were taken by cranes to the bays.

The forebay of the powerhouse was flooded in February 1952. The block of No. 1 hydro set was closed on the upstream side by the one set of repair dam beams available by this time. The block of No. 4 hydro set was left open to pass the discharge. The blocks of No. 2 and No. 3 hydro sets could not be closed, because the construction was not ready and this made access of the maintenance crane to the gate grooves impossible.

The following method was suggested and put into practice. The pressure of the headwater was directed to the guide vanes of the turbines which at that time were still without servomotors and forced lubrication units. For this purpose, the guide vane levers were equipped with special locks to keep them from opening under the pressure of the water. The conjugation lines between the vanes and the upper and lower stator rings were cemented with bituminous mats. The lock devices performed well under a head of 15 metres. During the period before the construction part was ready, and the gates could be installed in the blocks of No. 2 and No. 3 hydro sets, the entire head was held by the guide vanes of these turbines.

The total volume of installation and erection work at the spillway dam of the project came to 3,510 tons: 3,300 tons of steel structures were erected and 210 tons of machinery installed. The technological equipment of the



spillway dam consists of 24 segment gates 8.5 m in height and with 16-m spans, two emergency repair guards, crane support girders for the portal maintenance cranes, and two 37.5×2-ton portal cranes.

Ninety per cent of the erection and installation work on the dam had to be completed within four months. This was due to the fact that the concrete of the dam was ready, and it was necessary to prepare the segment gates to withstand the reservoir head. In order to accomplish this, the following sequence of operations had to be adopted.

To save time, the insertion parts of the emergency repair guards and segment gates were installed without recesses and were concreted at the same time as the main blocks of the dam. For this purpose, the insertion parts of the emergency repair guards (the operating, reverse and side lines, as well as the reinforcement wires) were assembled at the central assembly base No. 2 into rigid space trusses, all elements being mutually aligned within the tolerance limits of the assembly specifications. The side insertion parts of the segment gates were also first assembled on special stands. The insertion parts and conical support of the segment gates were assembled into a single block on a similar base. As soon as the concrete of the lower blocks was ready, the insertion parts were conveyed by rail to the concrete-delivery trestle, where they were put into place with the aid of the portal building cranes. After installment, the insertion parts were mutually aligned in each span. They were then loosened and made ready for concreting together with the main block. The insertion parts were checked after the forms were removed and it was found that no displacement of these parts had taken place during concreting of the blocks. This method of installing the insertion parts made it possible to complete this stage of the work three weeks sooner than usual. In order to exclude the laborious process of checking and assembling the segment gate in the span of the dam, it was decided to handle these two stages beforehand, i.e., before the concrete in the blocks of the dam was



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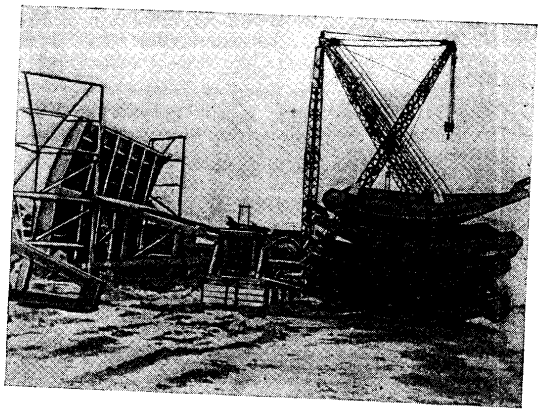

Fig. 58. Installing segment gates

ready. The segment gate was assembled on special racks and delivered to the stand with the oak and rubber packings in place. On the stand, legs were attached to the segment gate, after which it was given a complete check. After the check, the legs were detached, and the gates (now ready for installation) were piled up (Fig. 58).

A very difficult problem was how to deliver the assembled segment gate to the spillway dam. It was a question of getting the railway trucks with the segment gate between the gantries of the building cranes of the dam.

To do this, the segment gate was given an eccentric position with respect to the axis of the railway truck; special counterweights were required to ensure stability en route. The leaves of the segment gates delivered to the dam were installed by two 10-ton portal cranes which had to be reinforced for the purpose since the leaf of a segment gate weighs 30 tons.



First, the segment gate was delivered to a temporary covering put between the concrete-delivery trestle and the spillway dam. Then, with the aid of the same building cranes, it was turned about, placed in the required position, and secured, after which its legs were attached by the building cranes.

According to the first work plan, the maintenance cranes of the dam were to be assembled at their permanent site—the gate store of the dam. As was the case during the erection of the powerhouse cranes, the combined building and assembly system was employed, i.e., the cranes were erected simultaneously with the pouring of the concrete at the gate store on the earth dam, at a distance of about 700 m from the spillway dam. As soon as the concrete work on the gate store was completed and the crane rails of the gate store laid, both cranes turned on their motors (which were connected by a hose cable), passed across the earth dam, onto the crane rails of the gate store, and thence onto the crane rails of the dam. This made it possible for the cranes to help in mounting the last ten segment gates and to prepare the dam for the spring high water.

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CHAPTER EIGHT

## CONTROL OF QUALITY OF WORK AND INSPECTION OF STRUCTURES

Hydraulic structures that impound large quantities of water in reservoirs are constantly acted on by a head of water, by percolation, and the strong hydrodynamic force of the water flow during the passage of spring floods. These structures must be reliable at every point, because, as in the case of a chain, the whole is not stronger than its weakest link.

In normal working conditions, the most important parts of the hydraulic structures are under the water and are not accessible for daily inspection. Repairs are expensive and require extensive drainage. Therefore, large hydraulic structures are built to last a very long time. The work is done with special care and constant technical control. In order to maintain constant control of the installations, special instruments are imbedded in them during construction. Percolation under the structures, settling, and other phenomena can thus be detected.

In the process of construction of hydraulic installations it is important to see that all the technical specifications of the job are strictly observed, that the acts of technical inspection of the foundations and other hidden parts of the structures are in proper order. It is also important to supervise the taking of control samples of soil (Fig. 59) in the foundations of the structures, samples of the fill material, concrete, reinforcement, steel structures, and to supervise their testing. Both when building the structures (during the filling of the reservoir) and later, during regular operation,



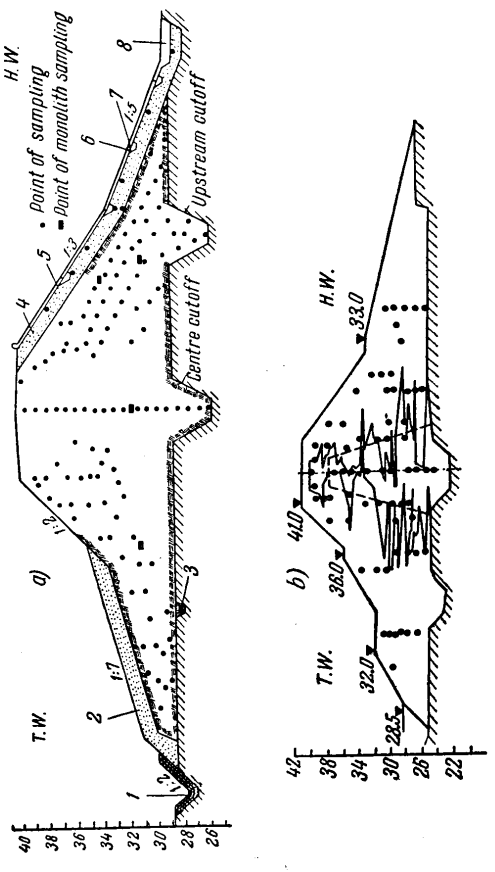


Fig. 59. Cross-section profiles of dam with spots where test samples have been taken indicated
a) cross section of sandy loam rolled-fill dam; b) cross section of hydraulic-fill sand dam.
1 and 3—header drainage trenches; 2 and 4—sand surcharge; 5—concrete facing; 6—longitudinal drainage trenches; 7—joints between slabs; 8—toe.

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systematic observations are made of the piezometric heads of water under the structures, of settling and deformations of the structures, of the state of the concrete, the work of the drainage systems and of other phenomena.

A technical inspection bureau, a geotechnical laboratory, and a laboratory for investigating building materials were established to handle technical inspection during construction.

*The Central Department of the technical Inspection Bureau* was attached to the construction management. In the other construction divisions there were groups of technical inspectors that handled round-the-clock control of the work and the approval of foundations, reinforcement, forms, concreting blocks and insertion parts of the steel structures and equipment. The more responsible jobs (the foundations of the main structures, insertion parts of the technological equipment, etc.) were approved by a central commission of the technical inspection bureau in the presence of representatives from the designing organization who exercised a so-called "designer" supervision, and of representatives of the laboratories and the Chief Engineer of the divisions in charge of the construction of the given installation. The acts of the central commission were approved by the Chief Engineer of the project.

*The Geotechnical Laboratory* was under the Chief Engineer of the project and consisted of: an engineering-geological department that handled the geological data of the foundation pits for the structures, and observation of hydrogeological phenomena; a geotechnical department that tested samples of soil and determined their compression properties, shearing strength, and other physical properties; a physico-mechanical department that determined the granulometric composition of the soils, their porosity, humidity, and other factors; and a chemical department that handled chemical tests of the composition of types of water and soil. The laboratory was equipped with the necessary instruments for testing and analyzing soils. The geotechni-



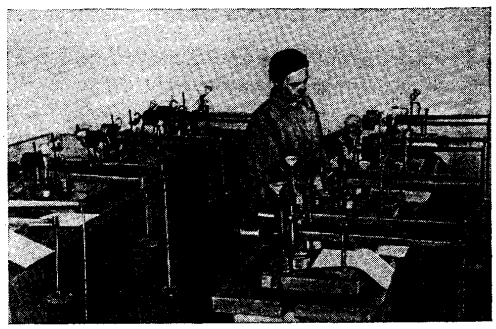

Fig. 60. Compression instruments in geotechnical laboratory

cal laboratory had a network of control-observation posts on the hydraulic-fill and rolled-fill jobs of the dam, at the pits of the structures, and on the filter and drainage jobs. The control posts had the necessary equipment for quick soil and filter-material tests. The number of control posts varied with the stage of the construction work.

To obtain geotechnical data, the following was done:

1) the physico-mechanical properties of cohesive and cohesionless soils in the natural foundations and in the rolled and hydraulic fills were investigated by taking and testing samples;

2) the chemical properties of soils and ground water were investigated by sampling and assaying;

3) filter materials were investigated by sampling and testing;

4) the level of the ground waters, and the types of rock deposits were determined by drilling and mining;

5) lithological maps, explanatory notes, engineering-geological maps, longitudinal and transverse geological records, tables, charts, geotechnical cross sections, engi-



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neering-geological and geotechnical reports on structures were compiled.

The basic equipment used by the geotechnical service of the Tsimlyanskaya project consisted of:

| | Quantity |
|---|---|
| 1) SKGU compression instruments | 30 |
| 2) Universal compression instruments (Fig. 60) | 10 |
| 3) Maslov-Lourier shear apparatuses | 4 |
| 4) 22- and 4-cup SU machines | 25 |
| 5) Tim-Darsey instruments (for determining the percolation properties of soils) | 11 |

During its existence, the geotechnical service designed and put to use several new-type instruments and developed new methods of geotechnical control: slurry samplers for testing slurries during hydraulic-fill work; an improved apparatus with 22 cups for determining the granulometric composition of cohesionless soils; a quick areometric method of determining the granulometric composition of cohesive soils with the use of a centrifugal machine; a high-speed method of determining the quality of filter material through the use of photo-standards, and others.

The work done by the Central Geotechnical Laboratory (in the departments and at the control posts) may be characterized as follows:

On the natural foundations and slopes:

295 chemical samples of ground water taken
2,400 chemical samples of soils taken
377 samples of cohesive soils (monolithic) taken
6,500 samples of natural-deposit sands taken
307 test holes dug (total—525.4 linear metres)
143 clearings made (total—522.3 linear metres)
69 wells sunk (total—510.0 linear metres)
14,180 linear metres of slopes sketched

Control of quality of structures and materials:

77 monoliths taken from depressions and from the body of the fill structures
42,554 samples taken from the fill structures
19,661 samples taken from the fill structures
4,122 samples taken from the shipping canal installations
19,857 samples taken from the filters and drainage systems
5,000 samples taken of filter material in the railway cars
1,029 miscellaneous samples taken



*The Laboratory of Concrete and Building Materials* was under the Chief Engineer of the project and handled: the selection of mixes and control of the quality of the concrete materials, of mortars, and hydro-insulation mixes; control of the manufacture of concrete, its pouring and further care, including the taking and testing of samples in the laboratory and in the structures; the necessary research work; the writing of instructions and approving of work done.

The laboratory had the following departments: concrete, cement, chemical, mechanical testing, and rough binding agents; the production control department and the technical data department. The laboratory was equipped with 100 to 200-ton hydraulic presses (Fig. 61), a 100-ton tensile-

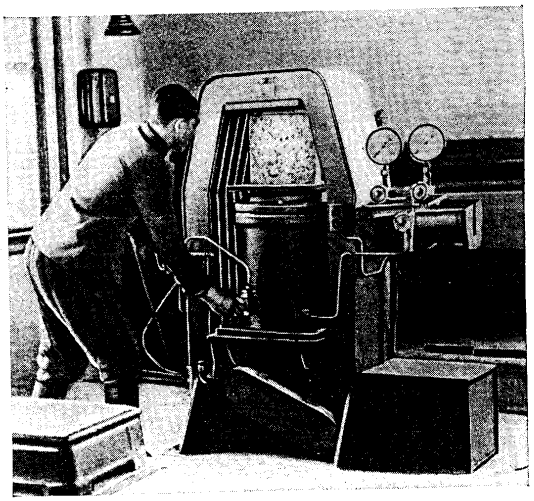

Fig. 61. 200-ton hydraulic press in concrete laboratory

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testing machine, and other necessary instruments. The laboratory maintained control of the work through a network of control posts situated at the different jobs and at the concrete plants. A brief description (based on laboratory data) of the concrete placed in the structures of the Tsimlyanskaya project is given below.

Grade 170-V4 concrete with puzzolan-Portland cement and grade 200V4M100 with Portland cement were those most often used in the structures of the project. Grades 250V4M100 and 300V4M150 were not often used.

As stated above, the average consumption of cement at the Tsimlyanskaya project (with allowance for losses of all kinds) came to 306 kg per cubic metre of concrete.

This excessive consumption of cement was due to the use of relatively fine-grained sand and to the fact that the concrete required had to have a plasticity of 6 to 8 cm. The use of a sulphite-alcohol wash as softening agent was of great importance in achieving the required plasticity, at the same time reducing cement consumption by 5 per cent.

The durability of the concrete placed in the structures was checked by compression tests of control cubes. Data of 25,000 cubes tested showed that for different types of concrete of grade 170 the rated durability for all structures was reached at an age of not over 90 days, and for grade 300 concrete, at an age of about one year.

The water permeability of the concrete was tested by injecting water into test channels (32 mm in diameter and 1.5 m deep) at pressures of 2 to 8 atm in the course of two hours. Freezing tests are still going on. The first results obtained after 80 and 100 test cycles are good.

An idea of the quality of the reinforcement-welding work may be gained from the fact that of 9,400 specimens only 0.9 per cent failed during the first test and required a second test after strengthening.

*Observations, during the construction period, of the settling and strain of the structures* and of the piezometric levels of the ground waters were handled by the geo-



technical laboratory, and later by the investigation departments attached to the hydrotechnical department of the management operating the structures.

The first observation data show that all structures are in normal working condition. The settling of the reinforced concrete dam is slowing down, and one year and six months after taking on the water pressure it is at an average of 16 cm at the upstream cutoff and 15 cm at the downstream cutoff, which is 32 to 40 per cent below the planned figures. The pressure of the structures on the ground is uneven, with an increase under the upstream and downstream slopes of approximately 1.5 times of the average, and with a corresponding decrease in the middle part. Settling of the powerhouse is slightly greater. On the shore section it is about 16 cm and on the river section 19 cm, and is slowing down. This is less than the project figures. Piezometer data show that the residual hydrodynamic pressure on the foot of the structures is between 10 and 12 per cent of the head acting on the structure. This is also less than provided for by the plan.

The position of the depression curves in the body of the earth dam is slightly below the planned position and indicates that the drainage systems are in normal working order. The total measured percolation through the body of the earth dam at a head of the order of 18 m was less than 0.5 cu m per second.

During the initial operation period, certain phenomena were observed that are of practical interest. On the 25th of June, during the filling of the reservoir, the slabs of the concrete facing of the upstream slope slipped down over an area of about 400 sq. m at the junction point of the earth dam and powerhouse. The volume of sand that slid from the slope amounted to approximately 6,000 cu m. The landslide included the conjugation cone directly, and hardly touched the body of the dam at all. The reason for the landslide was obviously the uplift of the water percolating from the pool during hydraulic-fill work in the conjugation



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depression of the earth dam and retaining wall. The protection slabs did not have any drainage openings to let out the percolation water. In addition, the lower part of the cone was filled with sand dumped in the winter time, and although according to control samples it had a consolidation of the order of 1.55-1.6, it created conditions favourable for a landslide due to abundant humidity while compacting. The section of the landslide was filled with crushed stone, gravel and rock, and covered with concrete slabs, and has been in a stable condition since.

In the middle of November, a strong storm arose on the reservoir with a wind of 31 m per sec. and waves up to 2.6 m high. Near the west-bank retaining wall, splashes of water above the gates were observed, and drops of water were carried by the wind to the motor traffic bridge and the roof of the gate store. At night, when the temperature dropped below zero, the service bridge and gates became covered with ice. At the same time, it was observed that the west bank of the reservoir was eroding with the formation of vertical cuts in the shore reaching to a height of several metres, where the waves splashed up to a height of 10 metres and more.

In the winter of 1952/53, during the period of thawing and strong winds, an ice sheet 15 to 20 cm thick was moved up onto the west bank, where in places the ice was heaped up on the shore into a mound over 5 m in height and several dozen metres wide. Nothing of this kind was observed during the winter within the immediate vicinity of the structures.

After snow storms, large quantities of snow accumulate on the crest of the dam along the parapet. For this reason, special snowploughs are needed to keep the service road on the crest of the dam clear in winter. In the spring, when the ice became soft, and during strong winds, the ice fields changed their position, and masses of broken-up ice collected on the slopes of the dam and, in places, were raised almost up to the parapet, i. e., to a height of 10 metres. A



large quantity of broken ice was observed to pass through the ship passage between the protecting dikes into the outer harbour.

The properties of percolation anisotropy in the flood-plain deposits and in the east-bank terrace above the flood plain were not fully taken account of in the technical plan. After the reservoir was filled in the spring of 1952, the level of the ground water rose to the surface, first in isolated spots and later over a large tailwater part of the west-bank and east-bank dam. In certain places it rose 2 and 3 m above the surface. Water appeared in the cellars of buildings in the workers' town. Conditions began to form that would favour swamping in the tailwater area.

In order to remedy this situation, it was decided to organize a drainage system through wells equipped with filters, to improve the discharge of drainage water by deepening the drainage trenches to 2 and 3 m below the surface of the ground, and in certain places to increase the surcharge by additional sand sluiced into place on the lower sections of the tailwater area.

A total of 378 wells with diameters ranging from 475 to 350 mm were sunk to depths of 10 to 30 metres. The wells were equipped chiefly with filters in the form of ready-made tubular blocks of porous concrete (as proposed by engineer A. N. Kalinin). Sectional reinforced concrete chutes were used to reinforce trenches made in floating soils.

The measures taken to improve the drainage system of the tailwater area of the dam made it possible to drain this swampy territory and to create more stable conditions for seepage in the earth dam.

In 1953, the spring water filled the Tsimlyanskaya reservoir to 10 cm above the normal backwater level called for in the plan. Nearly two cubic kilometres of excess-water was discharged through the sluiceways of the spillway dam.

During peak load hours, the turbines of the powerhouse



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developed 10 per cent more power than provided for by plan.

The completion of the Lenin Volga-Don Shipping Canal, the Tsimlyanskaya hydro project and the first section of the irrigation system is one more victory of peaceful creative labour and is an indication of the progress of Soviet science and engineering.

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Н. В. РАЗИН

**ЦИМЛЯНСКИЙ ГИДРОУЗЕЛ**

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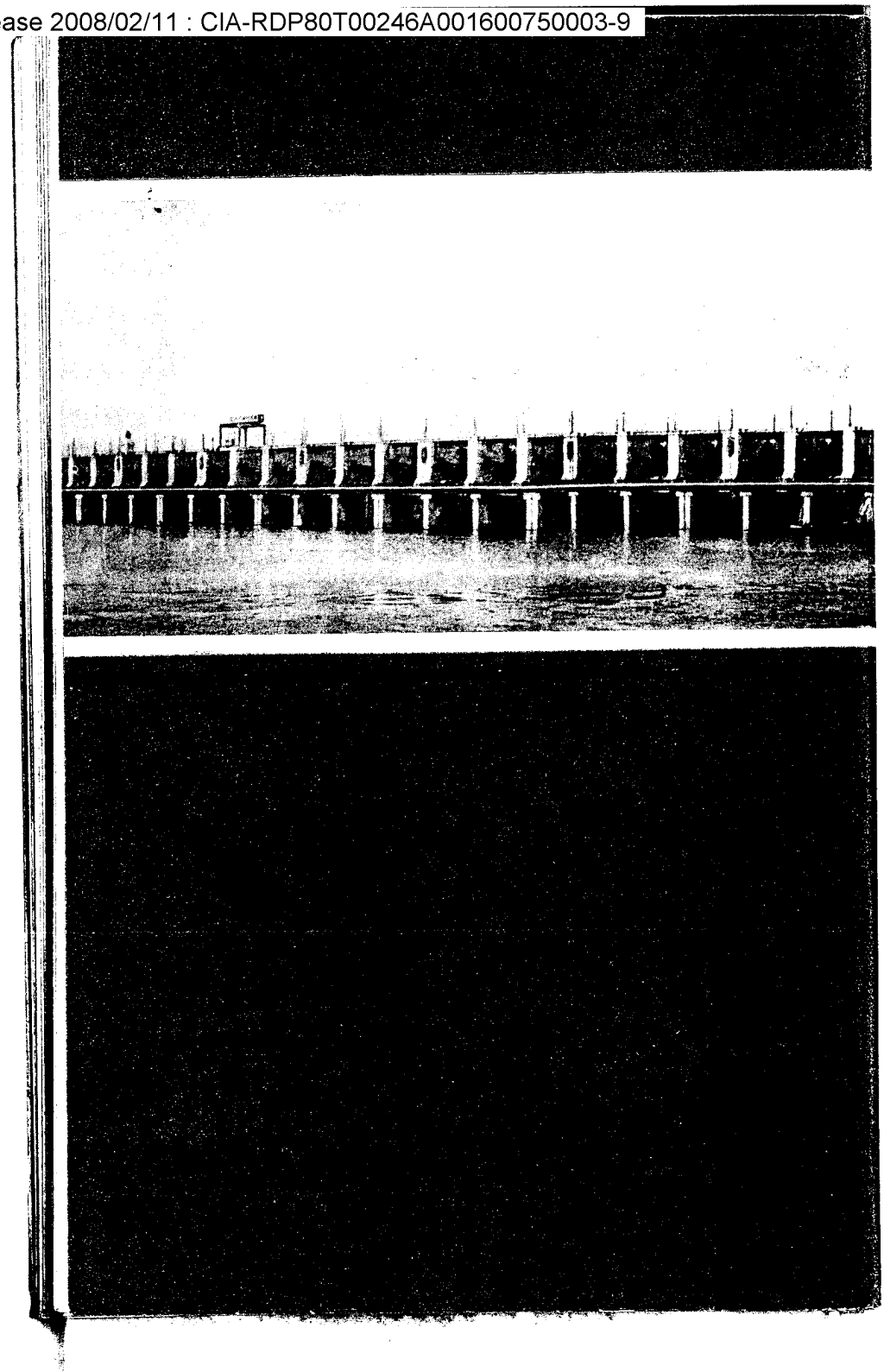

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